

Sourcery CodeBench Lite

ARM EABI

Sourcery CodeBench Lite 2012.03-56

Getting Started



Sourcery CodeBench Lite: ARM EABI: Sourcery CodeBench Lite 2012.03-56: Getting Started

CodeSourcery, Inc.

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Abstract

This guide explains how to install and build applications with Sourcery CodeBench Lite, CodeSourcery's customized and validated version of the GNU Toolchain. Sourcery CodeBench Lite includes everything you need for application development, including C and C++ compilers, assemblers, linkers, and libraries.

When you have finished reading this guide, you will know how to use Sourcery CodeBench from the command line.

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Preface

This preface introduces the Sourcery CodeBench Lite Getting Started guide. It explains the structure of this guide and describes the documentation conventions used.

1. Intended Audience

This guide is written for people who will install and/or use Sourcery CodeBench Lite. This guide provides a step-by-step guide to installing Sourcery CodeBench Lite and to building simple applications. Parts of this document assume that you have some familiarity with using the command-line interface.

2. Organization

This document is organized into the following chapters and appendices:

Chapter 1, “Quick Start”	This chapter includes a brief checklist to follow when installing and using Sourcery CodeBench Lite for the first time. You may use this chapter as an abbreviated guide to the rest of this manual.
Chapter 2, “Installation and Configuration”	This chapter describes how to download, install and configure Sourcery CodeBench Lite. This section describes the available installation options and explains how to set up your environment so that you can build applications.
Chapter 3, “Sourcery CodeBench Lite for ARM EABI”	This chapter contains information about using Sourcery CodeBench Lite that is specific to ARM EABI targets. You should read this chapter to learn how to best use Sourcery CodeBench Lite on your target system.
Chapter 4, “Using Sourcery CodeBench from the Command Line”	This chapter explains how to build applications with Sourcery CodeBench Lite using the command line. In the process of reading this chapter, you will build a simple application that you can use as a model for your own programs.
Chapter 5, “CS3™: The CodeSourcery Common Startup Code Sequence”	CS3 is CodeSourcery's low-level board support library. This chapter documents the boards supported by Sourcery CodeBench Lite and the compiler and linker options you need to use with them. It also explains how you can use and modify CS3-provided definitions for memory maps, system startup code and interrupt vectors in your own code.
Chapter 6, “Sourcery CodeBench Debug Sprite”	This chapter describes the use of the Sourcery CodeBench Debug Sprite for remote debugging. The Sprite allows you to debug programs running on a bare board without an operating system. This chapter includes information about the debugging devices and boards supported by the Sprite for ARM EABI.
Chapter 7, “Next Steps with Sourcery CodeBench”	This chapter describes where you can find additional documentation and information about using Sourcery CodeBench Lite and its components. It also provides information about Sourcery CodeBench subscriptions. CodeSourcery customers with Sourcery CodeBench subscriptions receive comprehensive support for Sourcery CodeBench.
Appendix A, “Sourcery CodeBench Lite Release Notes”	This appendix contains information about changes in this release of Sourcery CodeBench Lite for ARM EABI. You should

read through these notes to learn about new features and bug fixes.

Appendix B, “Sourcery CodeBench Lite Licenses” This appendix provides information about the software licenses that apply to Sourcery CodeBench Lite. Read this appendix to understand your legal rights and obligations as a user of Sourcery CodeBench Lite.

3. Typographical Conventions

The following typographical conventions are used in this guide:

<code>> command arg ...</code>	A command, typed by the user, and its output. The “>” character is the command prompt.
<code>command</code>	The name of a program, when used in a sentence, rather than in literal input or output.
<code>literal</code>	Text provided to or received from a computer program.
<code>placeholder</code>	Text that should be replaced with an appropriate value when typing a command.
<code>\</code>	At the end of a line in command or program examples, indicates that a long line of literal input or output continues onto the next line in the document.

Chapter 1

Quick Start

This chapter includes a brief checklist to follow when installing and using Sourcery CodeBench Lite for the first time. You may use this chapter as an abbreviated guide to the rest of this manual.

Sourcery CodeBench Lite for ARM EABI is intended for developers working on embedded applications or firmware for boards without an operating system, or that run an RTOS or boot loader. This Sourcery CodeBench configuration is not intended for Linux or uClinux kernel or application development.

Follow the steps given in this chapter to install Sourcery CodeBench Lite and build and run your first application program. The checklist given here is not a tutorial and does not include detailed instructions for each step; however, it will help guide you to find the instructions and reference information you need to accomplish each step.

You can find additional details about the components, libraries, and other features included in this version of Sourcery CodeBench Lite in Chapter 3, “Sourcery CodeBench Lite for ARM EABI”.

1.1. Installation and Set-Up

Install Sourcery CodeBench Lite on your host computer. You may download an installer package from the Sourcery CodeBench web site¹, or you may have received an installer on CD. The installer is an executable program that pops up a window on your computer and leads you through a series of dialogs to configure your installation. When the installation is complete, it offers to launch the Getting Started guide. For more information about installing Sourcery CodeBench Lite, including host system requirements and tips to set up your environment after installation, refer to Chapter 2, “Installation and Configuration”.

Install drivers for your debug device. If you plan to use the Sourcery CodeBench Debug Sprite, you may need to install drivers, libraries, or other software on your host system. Refer to Chapter 6, “Sourcery CodeBench Debug Sprite” for a list of supported devices and information about installing drivers and other device set-up. Sourcery CodeBench Lite also supports third-party debug devices that communicate via the GDB remote serial protocol. If you plan to use one of these devices, follow the manufacturer's directions to connect the device and install any required drivers or software.

1.2. Configuring Sourcery CodeBench Lite for the Target System

Identify your target board. On bare-metal targets, you must explicitly specify a linker script for your target board on your link command line. Supported boards are listed in Chapter 5, “CS3™: The CodeSourcery Common Startup Code Sequence”. You can also choose a simulator as your target board.

1.3. Building Your Program

Build your program with Sourcery CodeBench command-line tools. Create a simple test program, and follow the directions in Chapter 4, “Using Sourcery CodeBench from the Command Line” to compile and link it using Sourcery CodeBench Lite. On bare-metal targets, you must specify a linker script using the `-T` option on your link command line. Supported boards and linker scripts are listed in Chapter 5, “CS3™: The CodeSourcery Common Startup Code Sequence”.

1.4. Running and Debugging Your Program

The steps to run or debug your program depend on your target system and how it is configured. Choose the appropriate method for your target.

¹ <http://go.mentor.com/codebench/>

Run or debug your program in the simulator. Sourcery CodeBench Lite includes an instruction-set simulator, which provides an easy way to run or debug your program without requiring target hardware. The simulator can be run directly from the command line (see Section 4.3, “Running Applications in the Simulator”) or via the debugger (see Section 4.4, “Running Applications from GDB”).

Debug your program on the target using the Debug Sprite. You can use the Sourcery CodeBench Debug Sprite to load and execute your program on the target from the debugger. Refer to Section 4.4, “Running Applications from GDB” for instructions on using the Sprite from the GDB command line. Detailed reference material for the Sourcery CodeBench Debug Sprite, including information about supported debug devices, can be found in Chapter 6, “Sourcery CodeBench Debug Sprite”.

Debug your program on the target using a third-party debug device. Sourcery CodeBench supports debugging programs on the remote target using third-party debug devices that can communicate via the GDB remote serial protocol. For command-line GDB instructions, see Section 4.4, “Running Applications from GDB”.

Chapter 2

Installation and Configuration

This chapter explains how to install Sourcery CodeBench Lite. You will learn how to:

1. Verify that you can install Sourcery CodeBench Lite on your system.
2. Download the appropriate Sourcery CodeBench Lite installer.
3. Install Sourcery CodeBench Lite.
4. Configure your environment so that you can use Sourcery CodeBench Lite.

2.1. Terminology

Throughout this document, the term *host system* refers to the system on which you run Sourcery CodeBench while the term *target system* refers to the system on which the code produced by Sourcery CodeBench runs. The target system for this version of Sourcery CodeBench is `arm-none-eabi`.

If you are developing a workstation or server application to run on the same system that you are using to run Sourcery CodeBench, then the host and target systems are the same. On the other hand, if you are developing an application for an embedded system, then the host and target systems are probably different.

2.2. System Requirements

2.2.1. Host Operating System Requirements

This version of Sourcery CodeBench supports the following host operating systems and architectures:

- Microsoft Windows XP (SP1), Windows Vista, and Windows 7 systems using IA32, AMD64, and Intel 64 processors.
- GNU/Linux systems using IA32, AMD64, or Intel 64 processors, including Debian 3.1 (and later), Red Hat Enterprise Linux 3 (and later), SuSE Enterprise Linux 8 (and later), and Ubuntu 8.04 (and later).

Sourcery CodeBench is built as a 32-bit application. Therefore, even when running on a 64-bit host system, Sourcery CodeBench requires 32-bit host libraries. If these libraries are not already installed on your system, you must install them before installing and using Sourcery CodeBench Lite. Consult your operating system documentation for more information about obtaining these libraries.

Installing on Ubuntu and Debian GNU/Linux Hosts

The Sourcery CodeBench graphical installer is incompatible with the `dash` shell, which is the default `/bin/sh` for recent releases of the Ubuntu and Debian GNU/Linux distributions. To install Sourcery CodeBench Lite on these systems, you must make `/bin/sh` a symbolic link to one of the supported shells: `bash`, `csh`, `tcsh`, `zsh`, or `ksh`.

For example, on Ubuntu systems, the recommended way to do this is:

```
> sudo dpkg-reconfigure -plow dash
Install as /bin/sh? No
```

This is a limitation of the installer and uninstaller only, not of the installed Sourcery CodeBench Lite toolchain.

2.2.2. Host Hardware Requirements

In order to install and use Sourcery CodeBench Lite, you must have at least 512MB of available memory.

The amount of disk space required for a complete Sourcery CodeBench Lite installation directory depends on the host operating system and the number of target libraries included. When you start the graphical installer, it checks whether there is sufficient disk space before beginning to install. Note that the graphical installer also requires additional temporary disk space during the installation process. On Microsoft Windows hosts, the installer uses the location disk specified by the `TEMP` environ-

ment variable for these temporary files. If there is not enough free space on that volume, the installer prompts for an alternate location. On Linux hosts, the installer puts temporary files in the directory specified by the `IATEMPDIR` environment variable, or `/tmp` if that is not set.

2.2.3. Target System Requirements

See Chapter 3, “Sourcery CodeBench Lite for ARM EABI” for requirements that apply to the target system.

2.3. Downloading an Installer

If you have received Sourcery CodeBench Lite on a CD, or other physical media, then you do not need to download an installer. You may skip ahead to Section 2.4, “Installing Sourcery CodeBench Lite”.

You can download Sourcery CodeBench Lite from the Sourcery CodeBench web site¹. This free version of Sourcery CodeBench, which is made available to the general public, does not include all the functionality of CodeSourcery's product releases. If you prefer, you may instead purchase or register for an evaluation of CodeSourcery's product toolchains at the Sourcery CodeBench Portal².

Once you have navigated to the appropriate web site, download the installer that corresponds to your host operating system. For Microsoft Windows systems, the Sourcery CodeBench installer is provided as an executable with the `.exe` extension. For GNU/Linux systems Sourcery CodeBench Lite is provided as an executable installer package with the `.bin` extension. You may also install from a compressed archive with the `.tar.bz2` extension.

On Microsoft Windows systems, save the installer to the desktop. On GNU/Linux systems, save the download package in your home directory.

2.4. Installing Sourcery CodeBench Lite

The method used to install Sourcery CodeBench Lite depends on your host system and the kind of installation package you have downloaded.

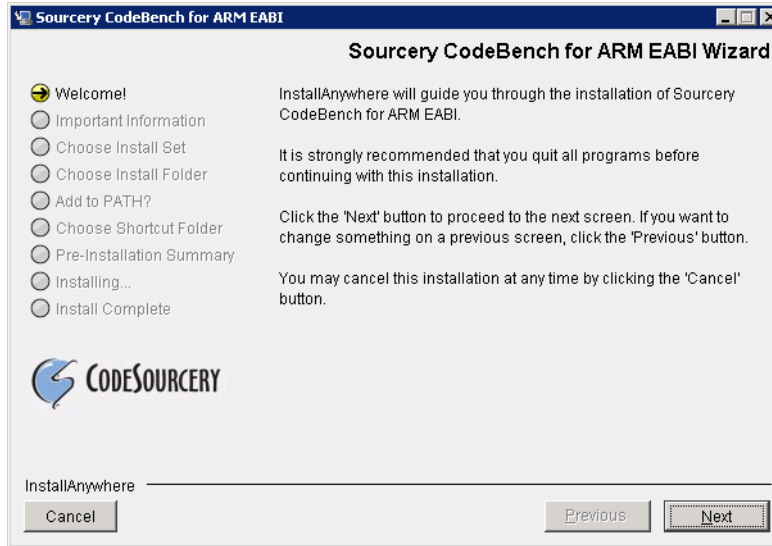
2.4.1. Using the Sourcery CodeBench Lite Installer on Microsoft Windows

If you have received Sourcery CodeBench Lite on CD, insert the CD in your computer. On most computers, the installer then starts automatically. If your computer has been configured not to automatically run CDs, open `My Computer`, and double click on the CD. If you downloaded Sourcery CodeBench Lite, double-click on the installer.

After the installer starts, follow the on-screen dialogs to install Sourcery CodeBench Lite. The installer is intended to be self-explanatory and on most pages the defaults are appropriate.

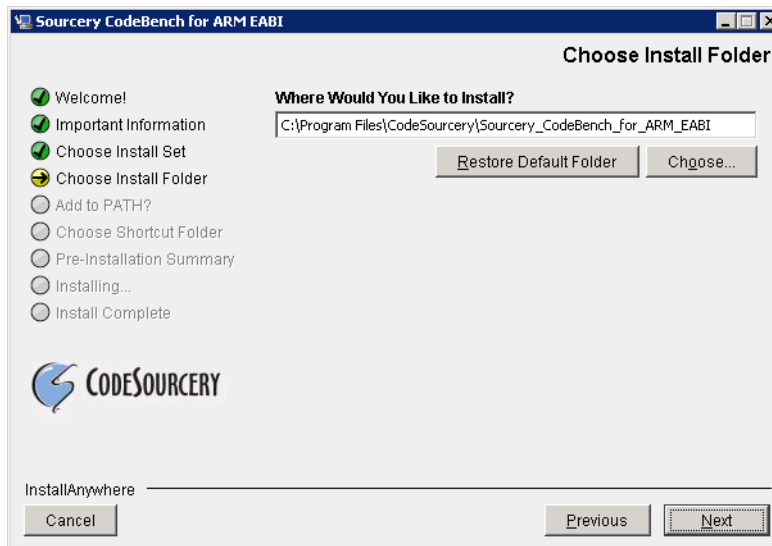
¹ <http://go.mentor.com/codebench/>

² <https://sourcery.mentor.com/GNUToolchain/>

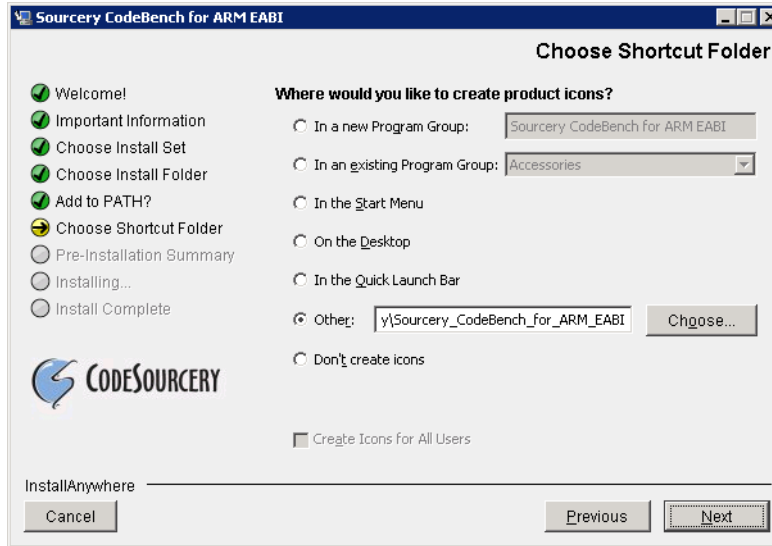


Running the Installer. The graphical installer guides you through the steps to install Sourcery CodeBench Lite.

You may want to change the install directory pathname and customize the shortcut installation.

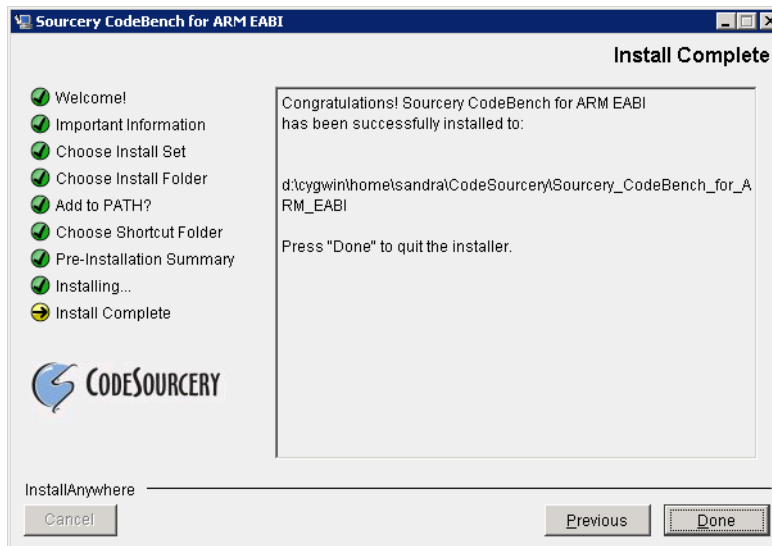


Choose Install Folder. Select the pathname to your install directory.



Choose Shortcut Folder. You can customize where the installer creates shortcuts for quick access to Sourcery CodeBench Lite.

When the installer has finished, it asks if you want to launch a viewer for the Getting Started guide. Finally, the installer displays a summary screen to confirm a successful install before it exits.



Install Complete. You should see a screen similar to this after a successful install.

If you prefer, you can run the installer in console mode rather than using the graphical interface. To do this, invoke the installer with the `-i console` command-line option. For example:

```
> /path/to/package.exe -i console
```

2.4.2. Using the Sourcery CodeBench Lite Installer on GNU/Linux Hosts

Start the graphical installer by invoking the executable shell script:

```
> /bin/sh ./path/to/package.bin
```

After the installer starts, follow the on-screen dialogs to install Sourcery CodeBench Lite. For additional details on running the installer, see the discussion and screen shots in the Microsoft Windows section above.

If you prefer, or if your host system does not run the X Window System, you can run the installer in console mode rather than using the graphical interface. To do this, invoke the installer with the `-i console` command-line option. For example:

```
> /bin/sh ./path/to/package.bin -i console
```

2.4.3. Installing Sourcery CodeBench Lite from a Compressed Archive

You do not need to be a system administrator to install Sourcery CodeBench Lite from a compressed archive. You may install Sourcery CodeBench Lite using any user account and in any directory to which you have write access. This guide assumes that you have decided to install Sourcery CodeBench Lite in the `$HOME/CodeSourcery` subdirectory of your home directory and that the filename of the package you have downloaded is `/path/to/package.tar.bz2`. After installation the toolchain will be in `$HOME/CodeSourcery/sourceryg++-2012.03`.

First, uncompress the package file:

```
> bunzip2 /path/to/package.tar.bz2
```

Next, create the directory in which you wish to install the package:

```
> mkdir -p $HOME/CodeSourcery
```

Change to the installation directory:

```
> cd $HOME/CodeSourcery
```

Unpack the package:

```
> tar xf /path/to/package.tar
```

2.5. Installing Sourcery CodeBench Lite Updates

If you have already installed an earlier version of Sourcery CodeBench Lite for ARM EABI on your system, it is not necessary to uninstall it before using the installer to unpack a new version in the same location. The installer detects that it is performing an update in that case.

If you are installing an update from a compressed archive, it is recommended that you remove any previous installation in the same location, or install in a different directory.

Note that the names of the Sourcery CodeBench commands for the ARM EABI target all begin with `arm-none-eabi`. This means that you can install Sourcery CodeBench for multiple target systems in the same directory without conflicts.

2.6. Setting up the Environment

As with the installation process itself, the steps required to set up your environment depend on your host operating system.

2.6.1. Setting up the Environment on Microsoft Windows Hosts

2.6.1.1. Setting the PATH

If you installed Sourcery CodeBench Lite using the graphical installer then you may skip this step. The installer does this setup for you.

In order to use the Sourcery CodeBench tools from the command line, you should add them to your PATH. In the instructions that follow, replace *installdir* with the full pathname of your Sourcery CodeBench Lite installation directory, including the drive letter.

To set the PATH on a Microsoft Windows Vista system, use the following command in a `cmd.exe` shell:

```
> setx PATH "%PATH%;installdir\bin"
```

To set the PATH on a system running Microsoft Windows 7, from the desktop bring up the Start menu and right click on Computer. Select Properties and click on Advanced system settings. Go to the Advanced tab, then click on the Environment Variables button. Select the PATH variable and click Edit. Add the string `;installdir\bin` to the end, and click OK.

To set the PATH on older versions of Microsoft Windows, from the desktop bring up the Start menu and right click on My Computer. Select Properties, go to the Advanced tab, then click on the Environment Variables button. Select the PATH variable and click the Edit. Add the string `;installdir\bin` to the end, and click OK.

You can verify that your PATH is set up correctly by starting a new `cmd.exe` shell and running:

```
> arm-none-eabi-g++ -v
```

Verify that the last line of the output contains: `Sourcery CodeBench Lite 2012.03-56`.

2.6.1.2. Working with Cygwin

Sourcery CodeBench Lite does not require Cygwin or any other UNIX emulation environment. You can use Sourcery CodeBench directly from the Windows command shell. You can also use Sourcery CodeBench from within the Cygwin environment, if you prefer.

The Cygwin emulation environment translates Windows path names into UNIX path names. For example, the Cygwin path `/home/user/hello.c` corresponds to the Windows path `c:\cygwin\home\user\hello.c`. Because Sourcery CodeBench is not a Cygwin application, it does not, by default, recognize Cygwin paths.

If you are using Sourcery CodeBench from Cygwin, you should set the `CYGPATH` environment variable. If this environment variable is set, Sourcery CodeBench Lite automatically translates Cygwin path names into Windows path names. To set this environment variable, type the following command in a Cygwin shell:

```
> export CYGPATH=cygpath
```

To resolve Cygwin path names, Sourcery CodeBench relies on the `cygpath` utility provided with Cygwin. You must provide Sourcery CodeBench with the full path to `cygpath` if `cygpath` is not in your PATH. For example:

```
> export CYGPATH=c:/cygwin/bin/cygpath
```

directs Sourcery CodeBench Lite to use `c:/cygwin/bin/cygpath` as the path conversion utility. The value of `CYGPATH` must be an ordinary Windows path, not a Cygwin path.

2.6.2. Setting up the Environment on GNU/Linux Hosts

If you installed Sourcery CodeBench Lite using the graphical installer then you may skip this step. The installer does this setup for you.

Before using Sourcery CodeBench Lite you should add it to your `PATH`. The command you must use varies with the particular command shell that you are using. If you are using the C Shell (`csh` or `tcsh`), use the command:

```
> setenv PATH installdir/bin:$PATH
```

If you are using Bourne Shell (`sh`), the Korn Shell (`ksh`), or another shell, use:

```
> PATH=installdir/bin:$PATH
> export PATH
```

If you are not sure which shell you are using, try both commands. In both cases, replace `installdir` with the full pathname of your Sourcery CodeBench Lite installation directory.

You may also wish to set the `MANPATH` environment variable so that you can access the Sourcery CodeBench manual pages, which provide additional information about using Sourcery CodeBench. To set the `MANPATH` environment variable, follow the same steps shown above, replacing `PATH` with `MANPATH`, and `bin` with `share/doc/sourceryg++-arm-none-eabi/man`.

You can test that your `PATH` is set up correctly by running the following command:

```
> arm-none-eabi-g++ -v
```

Verify that the last line of the output contains: `Sourcery CodeBench Lite 2012.03-56`.

2.7. Uninstalling Sourcery CodeBench Lite

The method used to uninstall Sourcery CodeBench Lite depends on the method you originally used to install it. If you have modified any files in the installation it is recommended that you back up these changes. The uninstall procedure may remove the files you have altered. In particular, the `arm-none-eabi` directory located in the install directory will be removed entirely by the uninstaller.

2.7.1. Using the Sourcery CodeBench Lite Uninstaller on Microsoft Windows

You should use the provided uninstaller to remove a Sourcery CodeBench Lite installation originally created by the graphical installer. Start the graphical uninstaller by invoking the Uninstall executable located in your installation directory, or use the uninstall shortcut created during installation. After the uninstaller starts, follow the on-screen dialogs to uninstall Sourcery CodeBench Lite.

You can run the uninstaller in console mode, rather than using the graphical interface, by invoking the Uninstall executable found in your Sourcery CodeBench Lite installation directory with the `-i console` command-line option.

To uninstall third-party drivers bundled with Sourcery CodeBench Lite, first disconnect the associated hardware device. Then use `Uninstall a program` (Vista and newer) or `Add or Remove`

Programs (older versions of Windows) to remove the drivers separately. Depending on the device, you may need to reboot your computer to complete the driver uninstall.

2.7.2. Using the Sourcery CodeBench Lite Uninstaller on GNU/Linux

You should use the provided uninstaller to remove a Sourcery CodeBench Lite installation originally created by the executable installer script. Start the graphical uninstaller by invoking the executable Uninstall shell script located in your installation directory. After the uninstaller starts, follow the on-screen dialogs to uninstall Sourcery CodeBench Lite.

You can run the uninstaller in console mode, rather than using the graphical interface, by invoking the Uninstall script with the `-i console` command-line option.

2.7.3. Uninstalling a Compressed Archive Installation

If you installed Sourcery CodeBench Lite from a `.tar.bz2` file, you can uninstall it by manually deleting the installation directory created in the install procedure.

Chapter 3

Sourcery CodeBench Lite for ARM EABI

This chapter contains information about features of Sourcery CodeBench Lite that are specific to ARM EABI targets. You should read this chapter to learn how to best use Sourcery CodeBench Lite on your target system.

3.1. Included Components and Features

This section briefly lists the important components and features included in Sourcery CodeBench Lite for ARM EABI, and tells you where you may find further information about these features.

Component	Version	Notes
GNU programming tools		
GNU Compiler Collection	4.6.3	Separate manual included.
GNU Binary Utilities	2.21.53	Includes assembler, linker, and other utilities. Separate manuals included.
Debugging support and simulators		
GNU Debugger	7.2.50	Separate manual included.
Sourcery CodeBench Debug Sprite for ARM	2012.03-56	See Chapter 6, “Sourcery CodeBench Debug Sprite”.
GDB Simulator	N/A	See Section 4.3, “Running Applications in the Simulator”.
Target libraries		
CodeSourcery Common Startup Code Sequence	2012.03-56	See Chapter 5, “CS3™: The CodeSourcery Common Startup Code Sequence”.
Newlib C Library	1.18.0	Separate manuals included.
Other utilities		
GNU Make	N/A	Build support on Windows hosts.
GNU Core Utilities	N/A	Build support on Windows hosts.

3.2. Library Configurations

Sourcery CodeBench Lite for ARM EABI includes the following library configuration.

ARMv4 - Little-Endian, Soft-Float	
Command-line option(s):	default
Library subdirectory:	./

ARMv4 Thumb - Little-Endian, Soft-Float	
Command-line option(s):	-mthumb
Library subdirectory:	tthumb/

ARMv7 Thumb-2 - Little-Endian, Soft-Float	
Command-line option(s):	-mthumb -march=armv7 -mfix-cortex-m3-ldrd
Library subdirectory:	tthumb2/

ARMv6-M Thumb - Little-Endian, Soft-Float	
Command-line option(s):	-mthumb -march=armv6-m
Library subdirectory:	armv6-m/

Sourcery CodeBench includes copies of run-time libraries that have been built with optimizations for different target architecture variants or other sets of build options. Each such set of libraries is referred to as a *multilib*. When you link a target application, Sourcery CodeBench selects the multilib matching the build options you have selected.

Sourcery CodeBench Lite's library support includes linker scripts that pull in appropriate CS3 startup code, as well as the libraries themselves. You can find these linker scripts in multilib-specific subdirectories of the `arm-none-eabi/lib` directory of your Sourcery CodeBench install.

3.3. Using Flash Memory

Sourcery CodeBench Lite supports development and debugging of applications loaded into flash memory on ARM EABI targets. There are three steps involved:

1. You must use an appropriate linker script that identifies the ROM memory region on your target board, and locates the program text within that region. Refer to Chapter 5, “CS3™: The Code-Sourcery Common Startup Code Sequence” for information about the boards supported by Sourcery CodeBench.
2. Next, load your program into the flash memory on your target board. You must use third-party tools to program the flash memory.
3. Finally, when debugging a program in flash memory, GDB must be told about the ROM region so that it knows where it must use hardware breakpoints to control program execution. If you are using the Sourcery CodeBench Debug Sprite to debug your program, the Sprite does this automatically, using the memory map provided in the board configuration file. Otherwise, you must provide this information explicitly.

When using GDB from the command line, you can mark the flash memory as read-only by using the command:

```
(gdb) mem start end ro
```

where *start* and *end* define the address range of the read-only memory region.

In addition to GDB's automatic use of hardware breakpoints in the ROM region, you can also set hardware breakpoints explicitly from the debugger. However, on many targets the number of available hardware breakpoints is very small. Furthermore, GDB also uses hardware breakpoints internally to implement commands such as `step`, `next`, and `finish`. Thus the number of breakpoints you can explicitly set in ROM may be fewer than the number of hardware breakpoints supported by the target system.

For example, ARM7TDMI cores support only one hardware breakpoint, which must also be used internally by the debugger if you set any software breakpoints in RAM. On ARM9 cores, there are two hardware breakpoints supported and one is consumed by the debugger if you set any software breakpoints.

3.4. Using VFP Floating Point

3.4.1. Enabling Hardware Floating Point

GCC provides three basic options for compiling floating-point code:

- Software floating point emulation, which is the default. In this case, the compiler implements floating-point arithmetic by means of library calls.
- VFP hardware floating-point support using the soft-float ABI. This is selected by the `-mfloat-abi=softfp` option. When you select this variant, the compiler generates VFP floating-point instructions, but the resulting code uses the same call and return conventions as code compiled with software floating point.
- VFP hardware floating-point support using the VFP ABI, which is the VFP variant of the Procedure Call Standard for the ARM® Architecture (AAPCS). This ABI uses VFP registers to pass function arguments and return values, resulting in faster floating-point code. To use this variant, compile with `-mfloat-abi=hard`.

You can freely mix code compiled with either of the first two variants in the same program, as they both use the same soft-float ABI. However, code compiled with the VFP ABI is not link-compatible with either of the other two options. If you use the VFP ABI, you must use this option to compile your entire program, and link with libraries that have also been compiled with the VFP ABI. For example, you may need to use the VFP ABI in order to link your program with other code compiled by the ARM RealView® compiler, which uses this ABI.

Sourcery CodeBench Lite for ARM EABI includes libraries built with software floating point, which are compatible with VFP code compiled using the soft-float ABI. While the compiler is capable of generating code using the VFP ABI, no compatible runtime libraries are provided in Sourcery CodeBench Lite. However, VFP hard-float libraries built with both ABIs are available to Sourcery CodeBench Standard and Professional Edition subscribers.

Note that, in addition to selecting hard/soft float and the ABI via the `-mfloat-abi` option, you can also compile for a particular FPU using the `-mfpu` option. For example, `-mfpu=neon` selects VFPv3 with NEON coprocessor extensions.

3.4.2. NEON SIMD Code

Sourcery CodeBench includes support for automatic generation of NEON SIMD vector code. Autovectorization is a compiler optimization in which loops involving normal integer or floating-point code are transformed to use NEON SIMD instructions to process several data elements at once.

To enable generation of NEON vector code, use the command-line options `-ftree-vectorize -mfpu=neon -mfloat-abi=softfp`. The `-mfpu=neon` option also enables generation of VFPv3 scalar floating-point code.

Sourcery CodeBench also includes support for manual generation of NEON SIMD code using C intrinsic functions. These intrinsics, the same as those supported by the ARM RealView® compiler, are defined in the `arm_neon.h` header and are documented in the 'ARM NEON Intrinsics' section of the GCC manual. The command-line options `-mfpu=neon -mfloat-abi=softfp` must be specified to use these intrinsics; `-ftree-vectorize` is not required.

3.4.3. Half-Precision Floating Point

Sourcery CodeBench for ARM EABI includes support for half-precision (16-bit) floating point, including the new `__fp16` data type in C and C++, support for generating conversion instructions when compiling for processors that support them, and library functions for use in other cases.

To use half-precision floating point, you must explicitly enable it via the `-mfp16-format` command-line option to the compiler. For more information about `__fp16` representations and usage from C and C++, refer to the GCC manual.

3.5. Fixed-Point Arithmetic

Sourcery CodeBench for ARM EABI includes experimental support for fixed-point arithmetic using a set of new data types, as described in the draft ISO/IEC technical report TR 18037. This support is provided for all ARM targets, and uses specialized instructions where available, e.g. saturating add and subtract operations on ARMv6T2 and above. Library functions are used for operations which are not natively supported on the target architecture.

This feature is a GNU extension, so is only available when the selected language standard includes GNU extensions (e.g. `-std=gnu90`, which is the default). Furthermore, only C is supported, not C++.

TR 18037 leaves up to the implementation the sizes of various quantities within the new data types it defines. For Sourcery CodeBench for ARM EABI, these are, briefly:

- `short _Fract`: One sign bit, 7 fractional bits
- `_Fract`: One sign bit, 15 fractional bits
- `long _Fract`: One sign bit, 31 fractional bits
- `unsigned short _Fract`: 8 fractional bits
- `unsigned _Fract`: 16 fractional bits
- `unsigned long _Fract`: 32 fractional bits
- `short _Accum`: One sign bit, 7 fractional bits, 8 integral bits
- `_Accum`: One sign bit, 15 fractional bits, 16 integral bits
- `long _Accum`: One sign bit, 31 fractional bits, 32 integral bits
- `unsigned short _Accum`: 8 fractional bits, 8 integral bits
- `unsigned _Accum`: 16 fractional bits, 16 integral bits
- `unsigned long _Accum`: 32 fractional bits, 32 integral bits

These values (and various other useful constants) are also defined in the header file `stdfix.h` for use in your programs. Note that there is currently no support for the new standard-library functions described in TR 18037, nor for the pragmas controlling precision of operations.

Fixed-point extensions are not currently supported by GDB, nor are they compliant with the ARM EABI (which does not specify anything about fixed-point types at present). Code using fixed-point types cannot be expected to interact properly (across ABI boundaries) with code generated by other compilers for the ARM architecture.

3.6. ABI Compatibility

The Application Binary Interface (ABI) for the ARM Architecture is a collection of standards, published by ARM Ltd. and other organizations. The ABI makes it possible to combine tools from different vendors, including Sourcery CodeBench and ARM RealView®.

Sourcery CodeBench implements the ABI as described in these documents, which are available from the ARM Information Center¹:

- BSABI - ARM IHI 0036B (28 October 2009)
- BPABI - ARM IHI 0037B (28 October 2009)
- EHABI - ARM IHI 0038A (28 October 2009)
- CLIBABI - ARM IHI 0039B (4 November 2009)
- AADWARF - ARM IHI 0040A (28 October 2009)
- CPPABI - ARM IHI 0041C (5 October 2009)
- AAPCS - ARM IHI 0042D (16 October 2009)
- RTABI - ARM IHI 0043C (19 October 2009)
- AAELF - ARM IHI 0044D (28 October 2009)
- ABI Addenda - ARM IHI 0045C (4 November 2009)

Sourcery CodeBench currently produces DWARF version 2, rather than DWARF version 3 as specified in AADWARF.

3.7. ARM Profiling Implementation

Profiling is enabled by means of the `-pg` compiler option. In this mode, the compiler inserts a call to `__gnu_mcount_nc` into every function prologue. However, no implementation of `__gnu_mcount_nc` is provided (to do so would be impossible without knowledge of the execution environment).

You must provide your own implementation of `__gnu_mcount_nc`. Here are the requirements:

- On exit, pop the top value from the stack, and place it in the `lr` register. The `sp` register should be adjusted accordingly. For example, this is how to write it as a stub function:

```
.globl __gnu_mcount_nc
.type __gnu_mcount_nc, %function
__gnu_mcount_nc:
    mov    ip, lr
    pop   { lr }
    bx    ip
```

- Preserve all other register state except for `r12` and the CPSR condition code bits. In particular all coprocessor state and registers `r0-r3` must be preserved.
- Record and count all occurrences of the function calls in the program. The caller can be determined from the `lr` value stored on the top of the stack (on entry to `__gnu_mcount_nc`), and the callee can be determined from the current value of the `lr` register (i.e. the caller of this function).

¹ <http://infocenter.arm.com>

- Arrange for the data to be saved to a file named `gmon.out` when the program exits (via `atexit`). Refer to the `gprof` profiler manual for more information.

3.8. Object File Portability

It is possible to create object files using Sourcery CodeBench for ARM EABI that are link-compatible with the GNU C library provided with Sourcery CodeBench for ARM GNU/Linux as well as with the CodeSourcery C Library or Newlib C Library provided with ARM bare-metal toolchains. These object files are additionally link-compatible with other ARM C Library ABI-compliant static linking environments and toolchains.

To use this feature, when compiling your files with the bare-metal ARM EABI toolchain define the preprocessor constant `_AEABI_PORTABILITY_LEVEL` to 1 before including any system header files. For example, pass the option `-D_AEABI_PORTABILITY_LEVEL=1` on your compilation command line. No special options are required when linking the resulting object files. When building applications for ARM EABI, files compiled with this definition may be linked freely with those compiled without it.

Files compiled in this manner may not use the functions `fgetpos` or `fsetpos`, or reference the type `fpos_t`. This is because Newlib assumes a representation for `fpos_t` that is not AEABI-compliant.

Note that object files are only portable from bare-metal toolchains to GNU/Linux, and not vice versa; object files compiled for ARM GNU/Linux targets cannot be linked into ARM EABI executables.

Chapter 4

Using Sourcery CodeBench from the Command Line

This chapter demonstrates the use of Sourcery CodeBench Lite from the command line.

4.1. Building an Application

This chapter explains how to build an application with Sourcery CodeBench Lite using the command line. As elsewhere in this manual, this section assumes that your target system is `arm-none-eabi`, as indicated by the `arm-none-eabi` command prefix.

Using an editor (such as `notepad` on Microsoft Windows or `vi` on UNIX-like systems), create a file named `main.c` containing the following simple factorial program:

```
#include <stdio.h>

int factorial(int n) {
    if (n == 0)
        return 1;
    return n * factorial (n - 1);
}

int main () {
    int i;
    int n;
    for (i = 0; i < 10; ++i) {
        n = factorial (i);
        printf ("factorial(%d) = %d\n", i, n);
    }
    return 0;
}
```

Compile and link this program using the command:

```
> arm-none-eabi-gcc -o factorial main.c -T script
```

Sourcery CodeBench requires that you specify a linker script with the `-T` option to build applications for bare-board targets. Linker errors like `undefined reference to `read'` are a symptom of failing to use an appropriate linker script. Default linker scripts are provided in `arm-none-eabi/lib`. Refer to Chapter 5, “CS3™: The CodeSourcery Common Startup Code Sequence” for information about the boards and linker scripts supported by Sourcery CodeBench Lite. You must also add the processor options for your board, as documented in that chapter, to your compile and link command lines.

There should be no output from the compiler. (If you are building a C++ application, instead of a C application, replace `arm-none-eabi-gcc` with `arm-none-eabi-g++`.)

4.2. Running Applications on the Target System

Consult your target board documentation for instructions on loading programs onto the target, and running them. Alternatively, you can use the Sourcery CodeBench Debug Sprite from within GDB to download and run programs on the target via a supported hardware debugging device.

4.3. Running Applications in the Simulator

Sourcery CodeBench Lite includes a simulator that you can use on the host system to run programs compiled for the target system. Since you do not need target hardware, this is the easiest way to try out Sourcery CodeBench.

To use the simulator run:

```
> arm-none-eabi-run factorial
```

You should see the expected output:

```
factorial(0) = 1
factorial(1) = 1
factorial(2) = 2
factorial(3) = 6
factorial(4) = 24
factorial(5) = 120
factorial(6) = 720
factorial(7) = 5040
factorial(8) = 40320
factorial(9) = 362880
```

You can also use the simulator to execute target programs when debugging with GDB. See Section 4.4, “Running Applications from GDB” for more information.

The simulator supports the ARMv4 (StrongARM), ARMv4T (ARM7TDMI, ARM920, ARM9TDMI), ARMv5, and ARMv5TE (ARM926, Xscale) instruction sets. The arm-none-eabi-run simulator also includes support for Thumb instructions.

4.4. Running Applications from GDB

You can run GDB, the GNU Debugger, on your host system to debug programs running remotely on a target board or system. You can also run and debug programs using the GDB simulator.

When starting GDB, give it the pathname to the program you want to debug as a command-line argument. For example, if you have built the factorial program as described in Section 4.1, “Building an Application”, enter:

```
> arm-none-eabi-gdb factorial
```

While this section explains the alternatives for using GDB to run and debug application programs, explaining the use of the GDB command-line interface is beyond the scope of this document. Please refer to the GDB manual for further instructions.

4.4.1. Connecting to the GDB Simulator

GDB includes a simulator that allows you to debug ARM EABI applications without target hardware. To start and connect to the simulator from within GDB, use this command:

```
(gdb) target sim
```

4.4.2. Connecting to the Sourcery CodeBench Debug Sprite

The Sourcery CodeBench Debug Sprite is a program that runs on the host system to support hardware debugging devices. You can use the Debug Sprite to run and debug programs on a target board without an operating system, or to debug an operating system kernel. See Chapter 6, “Sourcery CodeBench Debug Sprite” for detailed information about the supported devices.

You can start the Sprite directly from within GDB:

```
(gdb) target remote | arm-none-eabi-sprite arguments
```

Refer to Section 6.3, “Invoking Sourcery CodeBench Debug Sprite” for a full description of the Sprite arguments.

4.4.3. Connecting to an External GDB Server

From within GDB, you can connect to a running `gdbserver` or other debugging stub that uses the GDB remote protocol using:

```
(gdb) target remote host:port
```

where *host* is the host name or IP address of the machine the stub is running on, and *port* is the port number it is listening on for TCP connections.

4.4.4. Loading and Running Applications

Connecting to a bare-metal target or simulator from GDB does not cause your program to be loaded into target memory. You must do this explicitly from GDB after you connect:

```
(gdb) load
```

Alternatively, you can use third-party tools to load your application into flash memory before starting GDB.

To begin execution of your application, you should generally use the `continue` command:

```
(gdb) continue
```

However, you should use `run` instead of `continue` to start your program if you used `target sim` to connect:

```
(gdb) run
```

Chapter 5

CS3™: The CodeSourcery Common Startup Code Sequence

CS3 is CodeSourcery's low-level board support library. This chapter documents the boards supported by Sourcery CodeBench Lite and the compiler and linker options you need to use with them. It also explains how you can use and modify CS3-provided definitions for memory maps, system startup code and interrupt vectors in your own code.

Many developers turn to the GNU toolchain for its cross-platform consistency: having a single system support so many different processors and boards helps to limit risk and keep learning curves gentle. Historically, however, the GNU toolchain has lacked a consistent set of conventions for processor- and board-level initialization, language run-time setup, and interrupt and trap handler definition.

The CodeSourcery Common Startup Code Sequence (CS3) addresses this problem. For each supported system, CS3 provides a set of linker scripts describing the system's memory map, and a board support library providing generic reset, startup, and interrupt handlers. These scripts and libraries all follow a standard set of conventions across a range of processors and boards.

In addition to providing linker support, CS3's functionality is fully integrated with the Sourcery CodeBench Debug Sprite. For each supported board, CS3 provides the board file containing the memory map and initialization sequence required for debugging applications on the board via the Sprite, as documented in Section 6.9, "Supported Board Files".

This chapter is organized in two parts. The first part explains CS3 concepts:

- Section 5.1, "Linker Scripts" provides basic information you need to know in order to select an appropriate CS3-provided linker script for your ARM EABI board.
- CS3's program startup and termination model is discussed in Section 5.2, "Program Startup and Termination".
- Section 5.3, "Memory Layout" discusses the mapping from program sections to memory regions. It also explains how you can refer to memory regions using CS3-provided symbolic names from C, assembly language, or the linker script, and customize placement of code or data in your program.
- Section 5.4, "Interrupt Vectors and Handlers" covers CS3's interrupt handling model, and discusses how you can customize the CS3-provided interrupt vector tables.

The second part provides details about the CS3 implementation for ARM EABI:

- Section 5.5, "Supported Boards for ARM EABI" lists the boards supported by CS3 for ARM EABI, and the available linker scripts for them.
- Section 5.6, "Interrupt Vector Tables" documents the details of the provided interrupt vectors for CS3-supported devices.

5.1. Linker Scripts

When you build programs for ARM EABI targets, you must use a linker script. The linker script serves several purposes:

- It determines the memory addresses for placement of code and data sections.
- It defines symbolic names for memory regions present on the board, which you can use programmatically within your code.
- It provides appropriate program startup and termination code, and causes the linker to pull in any low-level board support libraries that are required to run code on the target.
- It optionally provides a *hosting* library for basic I/O functionality.
- It provides a default interrupt vector appropriate for the target processor.

When invoking the Sourcery CodeBench linker from the command line, you must explicitly supply a linker script using the `-T` option; otherwise a link error results.

CS3 may provide multiple linker scripts for different configurations using the same board. For example, on some boards CS3 may support running the program from either RAM or ROM (flash). Some CS3 link configurations are also designed to co-exist with, or be run from, a boot monitor on the target board. Simulator targets typically require different startup code configurations than hardware targets. In CS3 terminology, each of these different configurations is referred to as a *profile*.

The remainder of this section discusses profile and hosting selection considerations in more detail. You can find the full list of supported boards and linker scripts included in this release of Sourcery CodeBench Lite in Section 5.5, “Supported Boards for ARM EABI”.

5.1.1. Program and Data Placement

Many boards have both RAM and ROM (flash) memory devices. CS3 provides distinct linker scripts to place the application either entirely in RAM, or to place code and read-only data in ROM.

Some boards have very small amounts of RAM memory. If you use large library functions (such as `printf` and `malloc`), you may overflow the available memory. You may need to use the ROM-based profile for such programs, so that the program itself is stored in ROM. You may be able to reduce the total amount of memory used by your program by replacing portions of the Sourcery CodeBench runtime library and/or startup code.

5.1.2. Hosting and Semihosting

CS3 is designed to support boards without an operating system. To allow functions like `open` and `write` to work without operating system support, a *semihosting* feature is supported, in conjunction with the debugger.

With semihosting enabled, these system calls are translated into equivalent function calls on your host system. You can only use these function calls while connected to the debugger; if you try to use them when disconnected from the debugger, you will get a hardware exception.

Semihosting requires support from the remote GDB debugging stub or agent, as well as the debugger itself. The Sourcery CodeBench Debug Sprite implements semihosting for all supported devices. Semihosting is also supported by the GDB Simulator included with Sourcery CodeBench Lite. However, semihosting may not be supported by debugging stubs provided by third parties. If you are using a debug device that communicates with GDB using the GDB remote protocol, check the documentation for your device to see whether semihosting is supported.

A good use of semihosting is to display debugging messages. For example, this program prints a message on the debugger console on the host:

```
#include <unistd.h>

int main () {
    write (STDERR_FILENO, "Hello, world!\n", 14);
    return 0;
}
```

The hosted CS3 linker scripts provide the semihosting support, and as such programs linked with them may only be run with the debugger. For production code, or programs where memory usage is tightly constrained, use the unhosted CS3 linker scripts instead. These scripts provide stub versions of the system calls, which return an appropriate error value in `errno`. If such a stub system call is

required in the executable, the linker also produces a warning. Such a warning may indicate that you have left debugging code active, or that your program contains unused code.

As an alternative to semihosting via the debugger, some targets supported by CS3 can run a boot monitor that provides console I/O services and other basic system calls. CS3 can also provide hosting via these facilities; where a boot monitor is supported, this is noted in the board tables below. Unlike semihosting, hosting via the boot monitor can be used when running programs outside of the debugger.

5.1.3. Specifying a Linker Script

When using Sourcery CodeBench from the command line or from a `Makefile`, you must add `-T script` to your linking command, where `script` is the appropriate linker script. For example, to target Altera Cyclone III Cortex-M1 boards, you could link with `-T cycloneiii-cml-ram-hosted.ld`.

5.2. Program Startup and Termination

This section documents CS3's model for target initialization prior to invoking the `main` function of your program, and aspects of program termination that are left unspecified in the C and C++ standards. It explains how you can customize or override the default behavior for your application.

CS3 divides the startup sequence into three phases:

- The *hard reset phase* (`__cs3_reset`) includes actions such as initializing the memory controller and setting up the memory map.
- The *assembly initialization phase* (`__cs3_start_asm`) prepares the stack to run C code, and jumps to the C initialization function.
- The *C initialization phase* (`__cs3_start_c`) is responsible for initializing the data areas, running constructors for statically-allocated objects, and calling `main`.

The hard reset and assembly initialization phases are necessarily written in assembly language; at reset, there may not yet be stack to hold compiler temporaries, or perhaps even any RAM accessible to hold the stack. These phases do the minimum necessary to prepare the environment for running simple C code. Then, the code for the final phase may be written in C; CS3 leaves as much as possible to be done at this point.

The CodeSourcery board support library provides default code for all three phases. The hard reset phase is implemented by board- and profile-specific code. The assembly initialization phase is implemented by profile-specific code. The C initialization phase is implemented by generic code.

5.2.1. The Hard Reset Phase

This phase, which begins at `__cs3_reset`, is responsible for initializing board-specific registers, such as memory base registers and DRAM controllers, or scanning memory to check the available size. It is written in assembler and ends with a jump to `__cs3_start_asm`, which is where the assembly initialization phase begins.

The hard reset code is in a section named `.cs3.reset`. CS3 linker scripts define `__cs3_reset` as an alias for a board- and profile-specific entry point. You may override the CS3-provided reset code by defining your own `__cs3_reset` entry point in the `.cs3.reset` section.

Program execution always begins at `__cs3_reset`, whether the program is started from the reset vector, the debugger, or a boot monitor. However, the `__cs3_reset` code linked into the application

is typically non-empty only for ROM-based profiles. For example, in a RAM-based profile, resetting the memory controllers would overwrite the code being executed.

When using the Sourcery CodeBench Debug Sprite, the Sprite is responsible for carrying out the hard reset actions before the program is loaded onto the target. This is performed prior to execution of both RAM- and ROM-profile applications from the debugger. Thus, when debugging a ROM-profile application, hard reset is actually performed twice — once by the Sprite, and once by the application itself.

5.2.2. The Assembly Initialization Phase

This phase is responsible for initializing the stack pointer and creating an initial stack frame. The symbol `__cs3_start_asm` marks the entry point of the assembly initialization code. The assembly initialization phase ends with a call or jump to `__cs3_start_c`.

The assembly initialization phase is profile-specific. For example, while bare-board applications typically must initialize the stack themselves, CS3 also supports boot-monitor profiles where the stack is initialized by the boot monitor before it launches the application. Likewise, some simulators automatically initialize the stack pointer and initial stack frame on startup, while others require a supervisory operation on startup to determine the amount of available memory. Each of these scenarios requires different assembly initialization behavior.

Note that on bare-board targets setting the stack pointer explicitly in the assembly initialization phase is required even if the processor itself initializes the stack pointer automatically on reset. This is to support running programs from the debugger as well as from processor reset.

For backwards compatibility with previous versions of CS3, on RAM and ROM profiles the symbol `__cs3_start_asm` is actually an alias for a symbol named `_start`. However, referencing or defining `_start` directly is now deprecated.

The value of the symbol `__cs3_stack` provides the initial value of the stack pointer for profiles that must set it explicitly. The CodeSourcery linker scripts provide a default value for this symbol, which you may override by defining `__cs3_stack` yourself. See Section 5.3.3, “Heap and Stack Placement” for an example of a custom stack.

The initial stack frame is created for the use of ordinary C and C++ calling conventions. The stack should be initialized so that backtraces stop cleanly at this point; this might entail zeroing a dynamic link pointer, or providing hand-written DWARF call frame information.

The last action of the assembly initialization phase is to call the C function `__cs3_start_c`. This function never returns, and `__cs3_start_asm` need not be prepared to handle a return from it.

As with the hard reset code, the CodeSourcery board support library provides reasonable default assembly initialization code. However, you may provide your own code by providing a definition for `__cs3_start_asm`, either in an object file or a library.

5.2.3. The C Initialization Phase

Finally, C code can be executed. The C startup function is declared as follows:

```
void __cs3_start_c (void) __attribute__((noreturn));
```

This function performs the following steps:

- Initialize all `.data`-like sections by copying their contents. For example, ROM-profile linker scripts use this mechanism to initialize writable data in RAM from the read-only data program image.
- Clear all `.bss`-like sections.
- Run constructors for statically-allocated objects, recorded using whatever conventions are usual for C++ on the target architecture.

CS3 reserves priorities from 0 to 100 for use by initialization code. You can handle tasks like enabling interrupts, initializing coprocessors, pointing control registers at interrupt vectors, and so on by defining constructors with appropriate priorities.

- Call `main` as appropriate.
- Call `exit`, if it is available.

As with the hard reset and assembly initialization code, the CodeSourcery board support library provides a reasonable definition for the `__cs3_start_c` function. You may override this by providing a definition for `__cs3_start_c`, either in an object file or in a library.

5.2.4. Arguments to `main`

The CodeSourcery-provided definition of `__cs3_start_c` can pass command-line arguments to `main` using the normal C `argc` and `argv` mechanism if the board support package provides corresponding definitions for `__cs3_argc` and `__cs3_argv`. For example:

```
int __cs3_argc;  
char **__cs3_argv;
```

These variables should be initialized using a constructor function, which is run by `__cs3_start_c` after it initializes the data segment. Use the `constructor` attribute on the function definition:

```
__attribute__((constructor))  
static void __cs3_init_args (void) {  
    __cs3_argc = ...;  
    __cs3_argv = ...;  
}
```

The constructor function may have an arbitrary name; `__cs3_init_args` is used only for illustrative purposes here.

If definitions of `__cs3_argc` and `__cs3_argv` are not provided, then the default `__cs3_start_c` function invokes `main` with zero as the `argc` argument and a null pointer as `argv`.

5.2.5. Program Termination

A program running on an embedded system is usually designed never to exit — it runs until the system is powered down. The C and C++ standards leave it unspecified as to whether `exit` is called at program termination. If the program never exits, then there is no reason to include `exit`, facilities to run functions registered with `atexit`, or global destructors. This code would never be run and would therefore just waste space in the application.

The CS3 startup code, by itself, does not cause `exit` to be present in the application. It dynamically checks whether `exit` is present, and only calls it if it is. If you require `exit` to be present, either refer to it within your application, or add `-Wl,-u,exit` to the linking command line.

Similarly, code to register global destructors is only invoked when `atexit` is already in the executable; CS3, by itself, does not cause `atexit` to be present. If you require `atexit`, either refer to it within your application, or add `-Wl, -u, atexit` to the linking command line.

5.3. Memory Layout

Boards supported by CS3 can have multiple banks or regions of memory with different characteristics. This section describes how program sections are mapped onto memory regions, and how you can use these CS3 features to customize placement of your program's code or data in memory. CS3 also provides a uniform set of symbolic names for each region, allowing you to programmatically refer to each region's address range from C or assembly language as well as from the linker script.

5.3.1. Memory Regions and Program Sections

The regions that are available on a particular board are listed in the table for that board in Section 5.5, “Supported Boards for ARM EABI”, below. There are two kinds of regions: those documented as “Memory regions”, which are general-purpose memory banks that can be used for program or data storage; and those documented as “Other regions”, which typically correspond to memory-mapped control registers or other special-purpose storage.

CS3 supports boards that include both `ram` and `rom` memory regions. The `ram` region holds the `.data` and `.bss` sections, and the `.text` section in RAM profiles. In ROM profiles, the `rom` region holds the `.text` section and initialization values for the writable data sections.

In addition, all regions documented as “Memory regions” correspond to similarly-named program sections. For example, the linker script assigns the `.ram` section to the `ram` region.

More generally, for a memory region named `R`, CS3 linker scripts define a section named `.R`, which may contain initialized data or code. There is also a section named `.bss.R` for zero-initialized data (BSS), which is placed after the initialized data section for this region.

You can explicitly locate data or code in a section corresponding to a particular memory region using section attributes in your source C or C++ code. Section attributes are especially useful on code compiled for boards that include special memory banks, such as a fast on-chip cache memory, in addition to the default `ram` and/or `rom` regions. CS3's start-up code arranges for additional data-like sections to be initialized in the same way as the default `.data` section.

As an example to illustrate the attribute syntax, you can put a variable `v` in the `.ram` section using:

```
int v __attribute__((section (".ram")));
```

To declare a function `f` in this section, use:

```
int f (void) __attribute__((section (".ram"))) {...}
```

For more information about attribute syntax, see the GCC manual.

In addition to the `.R` and `.bss.R` sections, CS3 places a `.cs3.region-head.R` section at the beginning of each region `R`. Explicitly placing data in `.cs3.region-head.R` sections is discouraged, because CS3 itself may want to place items (like interrupt vector tables) at these locations. If there is a conflict, CS3 raises an error at link time.

Regions documented as “Other regions” in the tables in Section 5.5, “Supported Boards for ARM EABI” do not have corresponding program sections. Typically, these regions contain memory-mapped control and I/O registers and cannot be used for general data or program storage. If your program

needs to manipulate data in these regions, you can use the CS3 memory map access interface declared in `cs3.h`, as described in Section 5.3.2, “Programmatic Access to the CS3 Memory Map”.

Memory maps for boards supported by Sourcery CodeBench Lite for ARM EABI are documented in XML files in the `arm-none-eabi/lib/boards/` subdirectory of your Sourcery CodeBench installation directory.

5.3.2. Programmatic Access to the CS3 Memory Map

CS3 makes C declarations describing the memory regions on the target board available to your program via the header file `cs3.h`, which you can find in the `arm-none-eabi/include` directory within your install.

For each region named *R*, `cs3.h` declares a byte array variable `__cs3_region_start_R` at the region's start address, and a `size_t` variable `__cs3_region_size_R` to represent the total size of the region. These symbols are defined by the linker script and so may also be referenced from assembly language. Note that all regions are aligned on eight-byte boundaries and sizes are also multiples of eight bytes.

For memory regions that can correspond to program sections (as described in Section 5.3.1, “Memory Regions and Program Sections”), there are additional symbols `__cs3_region_init_R` and `__cs3_region_init_size_R` that describe constant data used to initialize the region. During the C initialization phase (Section 5.2, “Program Startup and Termination”), this data is copied into the lower part of the memory region. The symbol `__cs3_region_zero_size_R` represents the size of the zero-initialized `.bss.R` section following the initialized data. Any of these identifiers may actually be defined as a preprocessor macro that expands to an expression of the appropriate type and value.

To perform the memory region initializations during startup, CS3 internally uses the array variable `__cs3_regions`, which contains descriptors for all of the writable (RAM) memory regions. These descriptors are also exposed in `cs3.h`; refer to the header file for details.

5.3.3. Heap and Stack Placement

CS3 linker scripts provide default placement of the heap and stack in the RAM region. However, you can override the defaults by providing your own definitions of the associated CS3 variables. For example, you may put the heap and/or stack in some other memory region.

Heap placement is controlled by defining the symbol `__cs3_heap_start` at the beginning of the heap, and either the symbol `__cs3_heap_end` or the pointer variable `__cs3_heap_limit` to mark the end of the heap. For example, this fragment of C code places the heap in a region named `extsram`:

```
#define HEAPSIZE ... /* However big you want to make it. */
unsigned char __cs3_heap_start[HEAPSIZE]
    __attribute__((section(".bss.extsram"), aligned(8)));
unsigned char *__cs3_heap_limit = __cs3_heap_start + HEAPSIZE;
```

The default initial stack pointer for bare-metal profiles is given by the symbol `__cs3_stack`, and the stack grows downward from this address. Stack initialization is discussed in more detail in Section 5.2.2, “The Assembly Initialization Phase”.

You can find C declarations for the CS3 heap and stack symbols in the header file `cs3.h`.

The `cs3.h` header file also defines a macro for creating a custom stack. The custom stack is created as a block of RAM in the zero-initialized data section (BSS). The specified size must be a compile-time constant. To account for alignment, the final size of the stack may be a few bytes less than the requested size. The symbol `__cs3_stack` is initialized to point to the last extent of the stack block, and is 16-byte aligned. For example, the following fragment of C code creates a stack of 8192 bytes:

```
#include <cs3.h>
CS3_STACK(2 * 4096);
```

As indicated in Section 5.2.2, “The Assembly Initialization Phase”, there are cases where a boot monitor or simulator overrides a custom stack.

5.4. Interrupt Vectors and Handlers

CS3 provides standard handlers for interrupts, exceptions and traps, but also allows you to define your own handlers as needed. In this section, we use the term *interrupt* as a generic term for this entire class of events.

Different processors handle interrupts in various ways, but there are two general approaches:

- Some processors fetch an address from an array indexed by the interrupt number, and jump to that address. We call these *address vector* processors.
- Others multiply the interrupt number by some constant factor, add a base address, and jump directly to that address. Here, the interrupt vector consists of blocks of code, so we call these *code vector* processors.
- Still other processors use a more complicated descriptor mechanism for the interrupt table.

M-profile processors like the Cortex-M3 use the address vector model. Classic ARM processors (including ARM7/ARM9 as well as Cortex-A/R series processors) are technically code vector processors. However, each vector slot only holds a single instruction. CS3 emulates the address vector model on these processors by placing an indirect branch instruction in each slot of the real exception vector. The remainder of this section assumes that you have some understanding of the specific requirements for your target; refer to the architecture manuals if necessary.

5.4.1. ARM EABI Interrupt Vector Implementation

On address vector processors, the CS3 library provides an array of pointers to interrupt handlers named `__cs3_interrupt_vector_form`, where *form* identifies the particular processor variant the vector is appropriate for. Each entry in the vector holds a reference to a symbol named `__cs3_isr_name`, where *name* is the customary name of that interrupt on the processor, or a number if there is no consistently used name. You can find the interrupt vector details in Section 5.6, “Interrupt Vector Tables”. The particular vector used by a given CS3-supported board is documented in the tables in Section 5.5, “Supported Boards for ARM EABI”.

CS3 provides a reasonable default definition for each `__cs3_isr_name` handler. Many of these symbols are aliased to a common handler routine. If your program stops at a default interrupt handler, its name as shown in backtraces may therefore not correctly reflect which interrupt occurred.

To override an individual handler, provide your own definition for the appropriate `__cs3_isr_name` symbol. The definition need not be placed in any particular object file section.

To override the entire interrupt vector, you can define `__cs3_interrupt_vector_form`. You must place this definition in a section named `.cs3_interrupt_vector`. The linker script reports an error if the `.cs3_interrupt_vector` section is empty, to ensure that the definition of `__cs3_interrupt_vector_form` occupies the proper section.

You may define the vector in C with an array of pointers using the `section` attribute to place it in the appropriate section. For example, to override the interrupt vector on Altera Cyclone III Cortex-M1 boards, make the following definition:

```
typedef void handler(void);
handler *__attribute__((section (".cs3_interrupt_vector")))
__cs3_interrupt_vector_micro[] =
{ ... };
```

5.4.2. Writing Interrupt Handlers

Interrupt handlers typically require special call/return and register usage conventions that are target-specific and beyond the scope of this document. In many cases, normal C functions cannot be used as interrupt handlers. For example, the EABI requires that the stack be 8-byte aligned, but on some ARMv7-M processors, only 4-byte stack alignment is guaranteed when calling an interrupt vector. This can cause subtle runtime failures, usually when 8-byte types are used.

As an alternative to writing interrupt handlers in assembly language, on ARM targets they may be written in C using the `interrupt` attribute. This tells the compiler to generate appropriate function entry and exit sequences for an interrupt handler. For example, to override the `__cs3_isr_nmi` handler, use the following definition:

```
void __attribute__((interrupt)) __cs3_isr_nmi (void)
{
    ... custom handler code ...
}
```

On ARM targets, the `interrupt` attribute also takes an optional parameter to specify the type of interrupt. Refer to the GCC manual for more details about attribute syntax and usage.

5.5. Supported Boards for ARM EABI

CS3 provides support for the following boards on ARM EABI targets.

Altera Cyclone III Cortex-M1	
Processor name:	Cortex-M1
Processor options:	-mcpu=cortex-m1 -mthumb
Memory regions:	itcm, ram (SRAM), rom (Flash)
Interrupt vector:	__cs3_interrupt_vector_micro
Linker scripts:	RAM Hosted cycloneiii-cm1-ram-hosted.ld
	RAM Unhosted cycloneiii-cm1-ram.ld
	ROM Hosted cycloneiii-cm1-rom-hosted.ld
	ROM Unhosted cycloneiii-cm1-rom.ld

ARM M-profile Simulator		
Processor name:	Cortex-M3	
Processor options:	-mcpu=cortex-m3 -mthumb	
Memory regions:	ram	
Interrupt vector:	__cs3_interrupt_vector_micro	
Linker scripts:	Simulator Hosted	generic-m-hosted.ld
	Simulator Unhosted	generic-m.ld

ARM Simulator		
Processor name:	unspecified	
Processor options:	none	
Memory regions:	ram	
Interrupt vector:	__cs3_interrupt_vector_arm	
Linker scripts:	Simulator Hosted	generic-hosted.ld
	Simulator Unhosted	generic.ld

ARM Simulator (VFP)		
Processor name:	unspecified	
Processor options:	none	
Memory regions:	ram	
Interrupt vector:	__cs3_interrupt_vector_arm	
Linker scripts:	Simulator Hosted	generic-vfp-hosted.ld
	Simulator Unhosted	generic-vfp.ld

ARMulator (RDI)		
Processor name:	unspecified	
Processor options:	none	
Memory regions:	ram	
Interrupt vector:	__cs3_interrupt_vector_arm	
Linker scripts:	RAM Hosted	armulator-ram-hosted.ld
	RAM Unhosted	armulator-ram.ld

Xilinx Zynq-7000		
Processor name:	Cortex-A9	
Processor options:	-mcpu=cortex-a9	
Memory regions:	ram (256MB DDR SDRAM), rom (64MB NOR Flash Memory)	
Interrupt vector:	__cs3_interrupt_vector_arm	
Linker scripts:	RAM Hosted	zynq7000-ram-hosted.ld
	RAM Unhosted	zynq7000-ram.ld
	ROM Hosted	zynq7000-rom-hosted.ld
	ROM Unhosted	zynq7000-rom.ld

5.6. Interrupt Vector Tables

5.6.1. __cs3_interrupt_vector_arm

The ARM interrupt vector table (__cs3_interrupt_vector_arm) contents are:

Number	Name	Meaning
0	__cs3_reset	Reset entry point
1	__cs3_isr_undef	Undefined Instruction
2	__cs3_isr_swi	Software Interrupt/Supervisor Call
3	__cs3_isr_pabort	Prefetch Abort
4	__cs3_isr_dabort	Data Abort
5	__cs3_isr_reserved	
6	__cs3_isr_irq	External Interrupt (IRQ)
7	__cs3_isr_fiq	Fast Interrupt (FIQ)

5.6.2. __cs3_interrupt_vector_micro

The Microcontroller Profile interrupt vector table (__cs3_interrupt_vector_micro) contents are:

Number	Name	Meaning
0	__cs3_stack	Initial stack pointer
1	__cs3_reset	Reset entry point
2	__cs3_isr_nmi	Non Maskable Interrupt
3	__cs3_isr_hard_fault	Hardware fault
4	__cs3_isr_mpu_fault	MPU fault
5	__cs3_isr_bus_fault	Bus fault
6	__cs3_isr_usage_fault	Usage fault
7..10	__cs3_isr_reserved_7..10	Reserved for future use
11	__cs3_isr_svcall	System Vector Call
12	__cs3_isr_debug	Debug interrupt

Number	Name	Meaning
13	__cs3_isr_reserved_13	Reserved for future use
14	__cs3_isr_pendsv	
15	__cs3_isr_systick	System Ticker
16..47	__cs3_isr_external_0..31	External interrupt

Chapter 6

Sourcery CodeBench Debug Sprite

This chapter describes the use of the Sourcery CodeBench Debug Sprite for remote debugging. The Sprite allows you to debug programs running on a bare board without an operating system. This chapter includes information about the debugging devices and boards supported by the Sprite for ARM EABI.

Sourcery CodeBench Lite contains the Sourcery CodeBench Debug Sprite for ARM EABI. This Sprite is provided to allow debugging of programs running on a bare board. You can use the Sprite to debug a program when there is no operating system on the board, or for debugging the operating system itself. If the board is running an operating system, and you wish to debug a program running on that OS, you should use the facilities provided by the OS itself (for instance, using `gdbserver`).

The Sprite acts as an interface between GDB and external debug devices and libraries. Refer to Section 6.3, “Invoking Sourcery CodeBench Debug Sprite” for information about the specific devices supported by this version of Sourcery CodeBench Lite.

Important

The Sourcery CodeBench Debug Sprite is not part of the GNU Debugger and is not free or open-source software. You may use the Sourcery CodeBench Debug Sprite only with the GNU Debugger. You may not distribute the Sourcery CodeBench Debug Sprite to any third party.

6.1. Probing for Debug Devices

Before running the Sourcery CodeBench Debug Sprite for the first time, or when attaching new debug devices to your host system, it is helpful to verify that the Sourcery CodeBench Debug Sprite recognizes your debug hardware. From the command line, invoke the Sprite with the `-i` option:

```
> arm-none-eabi-sprite -i
```

This prints out a list of supported device types. For devices that can be autodetected, it additionally probes for and prints out a list of attached devices. For instance:

```
Sourcery CodeBench Debug Sprite for ARM
(Sourcery CodeBench Lite 2012.03-56)
armusb: [speed=<n:0-7>] Stellaris USB
  armusb:///0B01000C - Stellaris Evaluation Board (0B01000C)
rdi: (rdi-library=<file>&rdi-config=<file>) RDI Device
  rdi:/// - RDI Device
```

This shows that Stellaris USB and RDI devices are supported. The exact set of supported devices depends on your host system and the version of Sourcery CodeBench you have installed; refer to Section 6.3, “Invoking Sourcery CodeBench Debug Sprite” for complete information.

Note that it may take several seconds for the Debug Sprite to probe for all types of supported devices.

6.2. Debug Sprite Example

Start by compiling and linking a simple test program for your target board, following the instructions in Chapter 4, “Using Sourcery CodeBench from the Command Line”. Use the `-g` option to tell the compiler to generate debugging information.

To build the `factorial` program to run on the ARMulator simulator, which can communicate with the Sprite via the RDI protocol, use:

```
> arm-none-eabi-gcc -g -Tarmulator-ram-hosted.ld main.c \
  -o factorial
```

Next start the debugger on your host system:

```
> arm-none-eabi-gdb factorial
```

The command for connecting GDB to the board depends on the debug device you are using; this is described in more detail in Section 6.3, “Invoking Sourcery CodeBench Debug Sprite”. If you are connecting via RDI, you must specify the full path to the RDI library file and configuration file for that library. Use quotes to escape the Sprite argument syntax from the shell. For example, use a command like this to connect to the ARMulator:

```
(gdb) target remote | arm-none-eabi-sprite \
  "rdi:///?rdi-library=library&rdi-config=config" armulator
```

The Sprite prints some status messages as it connects to your debug device and target board. If the connection is successful, you should see output similar to:

```
arm-none-eabi-sprite:Target reset
0x00008936 in ?? ()
(gdb)
```

Next, use GDB to load your program onto the target board.

```
(gdb) load
```

At this point you can use GDB to control the execution of your program as required. For example:

```
(gdb) break main
(gdb) continue
```

6.3. Invoking Sourcery CodeBench Debug Sprite

The Debug Sprite is invoked as follows:

```
> arm-none-eabi-sprite [options] device-url board-file
```

The *device-url* specifies the debug device to use to communicate with the board. It follows the standard format:

```
scheme:scheme-specific-part[?device-options]
```

Most device URL schemes also follow the regular format:

```
scheme:[//hostname:[port]]/path[?device-options]
```

The meanings of *hostname*, *port*, *path* and *device-options* parts depend on the *scheme* and are described below. The following schemes are supported in Sourcery CodeBench Lite for ARMEABI:

rdi Use an RDI debugging device. Refer to Section 6.5, “Remote Debug Interface Devices”.

flashpro Use a FlashPro debugging device. Refer to Section 6.6, “Actel FlashPro Devices”.

altera Use an Altera FPGA. Refer to Section 6.7, “Altera Devices”.

The optional *?device-options* portion is allowed in all schemes. These allow additional device-specific options of the form *name=value*. Multiple options are concatenated using *&*.

The *board-file* specifies an XML file that describes how to initialize the target board, as well as other properties of the board used by the debugger. If *board-file* refers to a file (via a relative or absolute pathname), it is read. Otherwise, *board-file* can be a board name, and the toolchain's board directory is searched for a matching file. See Section 6.9, “Supported Board Files” for the list of supported boards, or invoke the Sprite with the `-b` option to list the available board files. You can also write a custom board file; see Section 6.10, “Board File Syntax” for more information about the file format.

Both the *device-url* and *board-file* command-line arguments are required to correctly connect the Sprite to a target board.

6.4. Sourcery CodeBench Debug Sprite Options

The following command-line options are supported by the Sourcery CodeBench Debug Sprite:

- `-b` Print a list of *board-file* files in the board config directory.
- `-h` Print a list of options and their meanings. A list of *device-url* syntaxes is also shown.
- `-i` Print a list of the accessible devices. If a *device-url* is also specified, only devices for that device type are scanned. Each supported device type is listed along with the options that can be appended to the *device-url*. For each discovered device, the *device-url* is printed along with a description of that device.
- `-l [host]:port` Specify the host address and port number to listen for a GDB connection. If this option is not given, the Debug Sprite communicates with GDB using stdin and stdout. If you start the Sprite from within GDB using the `target remote | arm-none-eabi-sprite ...` command, you do not need this option.
- `-m` Listen for multiple sequential connections. Normally the Debug Sprite terminates after the first connection from GDB terminates. This option instead makes it listen for a subsequent connection. To terminate the Sprite, open a connection and send the string `END\n`.
- `-q` Do not print any messages.
- `-v` Print additional messages.

If any of `-b`, `-i` or `-h` are given, the Debug Sprite terminates after providing the information rather than waiting for a debugger connection.

6.5. Remote Debug Interface Devices

Remote Debug Interface (RDI) devices are supported. The RDI device URL accepts no hostname, port or path components, so the *device-url* is specified as follows:

```
rdi:[:///][?device-options]
```

The following *device-options* are required:

- `rdi-library=library` Specify the library (DLL or shared object) implementing the RDI target you wish to use.

`rdi-config=configfile` Specify a file containing configuration information for *library*. The format of this file is specific to the RDI library you are using, but tends to constitute a list of *key=value* pairs. Consult the documentation of your RDI library for details.

6.6. Actel FlashPro Devices

On Windows hosts, Sourcery CodeBench Lite supports FlashPro devices used with Actel Cortex-M1 development kits.

For FlashPro devices, the *device-url* has the following form:

```
flashpro:[//usb12345/][?jtagclock=rate]
```

The optional *usb12345* part indicates the ID of the FlashPro device to connect to, which is useful if you have more than one such device attached to your computer. If the ID is omitted, the Debug Sprite connects automatically to the first detected FlashPro device. You can enumerate the connected FlashPro devices by invoking the Sprite with the `-i` switch, as follows:

```
> arm-none-eabi-sprite -i flashpro:
```

The `jtagclock` option allows the communication speed with the target board to be altered. The *rate* is specified in Hz and may range between 93750 and 4000000. The default is 93750, the slowest speed supported by the FlashPro device. Depending on your target board, you may be able to increase this rate, but beware that communication errors may occur above a certain threshold. If you encounter communication errors with a higher-than-default speed selected, try reducing the speed.

6.6.1. Installing FlashPro Windows drivers

Windows drivers for the FlashPro device are included with the FlashPro software provided by Actel. Refer to Actel's documentation for details on installing this software. You must use the Actel FlashPro software to configure the FPGA on your Cortex-M1 board, but it does not need to be running when using the Debug Sprite.

Once you have set up your board using the FlashPro software, you can check that it is recognized by the Sourcery CodeBench Debug Sprite by running the following command:

```
> arm-none-eabi-sprite -i
flashpro: [jtagclock=<n:93750-4000000>] FlashPro
  flashpro://usb12345/ - FlashPro Device
  ...
```

If output similar to the above does not appear, your FlashPro device is not working correctly. Contact CodeSourcery for further guidance in that case.

6.7. Altera Devices

The Debug Sprite can be used to debug applications running on a Cortex-M1 core embedded in an Altera FPGA supporting the System-Level Debug (SLD) architecture. Currently, the Sprite supports the Cyclone III FPGA Starter board on Microsoft Windows hosts.

The Debug Sprite accepts two forms of the *device-url* for Altera devices. For the common case where you have only one Altera Cortex-M1 device configured, you can use simply:


```
altera://
```

The full form of the *device-url* is:

```
altera://usbX/hubY/nodeZ
```

where *X*, *Y*, and *Z* are non-negative integers. The SLD architecture forms a hierarchy; there may be multiple USB Blaster devices (numbered by *X*), multiple Altera FPGAs (numbered by *Y*) per USB Blaster, and multiple nodes (numbered by *Z*) per FPGA.

The Debug Sprite can autodetect connected Altera Cortex-M1 devices. Invoking the Sprite with the `-i` option, as described in Section 6.1, “Probing for Debug Devices”, displays the *device-url* for each detected device:

```
> arm-none-eabi-sprite -i
...
altera: Altera SLD Hub
  altera://usb0/hub0/node1 - Altera Cortex-M Device
```

6.7.1. Setting Up the Altera Device

Follow these steps for initial installation and set up of the Altera device.

1. Install Quartus II Web Edition (or any equivalent), available from Altera.
2. Install drivers for USB Blaster, also available from Altera.
3. Install Sourcery CodeBench Lite for ARMEABI. See Chapter 2, “Installation and Configuration”.
4. Connect the board and the host computer with a USB cable.
5. Turn on the board.
6. Use Quartus II to download a `.sof` file including a Cortex-M1 core to the FPGA.
7. Use `arm-none-eabi-sprite -i` to verify that the Sprite can detect the installed Cortex-M1 core.

6.7.2. Hardware Breakpoints

The Cortex-M1 core only permits hardware breakpoints to be set in the first 512MB of its address space. Because both external SRAM and flash memory are located at higher addresses, you cannot set hardware breakpoints in these memory regions.

6.8. Debugging a Remote Board

You can run the Sourcery CodeBench Debug Sprite on a different machine from the one on which GDB is running. For example, if your board is connected to a machine in your lab, you can run the debugger on your laptop and connect to the remote board. The Sourcery CodeBench Debug Sprite must run on the machine that is connected to the target board. You must have Sourcery CodeBench installed on both machines.

To use this mode, you must start the Sprite with the `-l` option and specify the port on which you want it to listen. For example:

```
> arm-none-eabi-sprite -l :10000 device-url board-file
```

starts the Sprite listening on port 10000.

When running GDB from the command line, use the following command to connect GDB to the remote Sprite:

```
(gdb) target remote host:10000
```

where *host* is the name of the remote machine. After this, debugging is just as if you are debugging a target board connected to your host machine.

For more detailed instructions on using the Sourcery CodeBench Debug Sprite in this way, please refer to the Sourcery CodeBench Knowledge Base¹.

6.9. Supported Board Files

The Sourcery CodeBench Debug Sprite for ARM EABI includes support for the following target boards. Specify the appropriate *board-file* as an argument when invoking the Sprite from the command line.

Board	Config
Altera Cyclone III Cortex-M1	cycloneiii-cm1
ARMulator (RDI)	armulator
Xilinx Zynq-7000	zynq7000

6.10. Board File Syntax

The *board-file* can be a user-written XML file to describe a non-standard board. The Sourcery CodeBench Debug Sprite searches for board files in the `arm-none-eabi/lib/boards` directory in the installation. Refer to the files in that directory for examples.

The file's DTD is:

```
<!-- Board description files

Copyright (c) 2007-2012 Mentor Graphics Corporation.

THIS FILE CONTAINS PROPRIETARY, CONFIDENTIAL, AND TRADE
SECRET INFORMATION OF MENTOR GRAPHICS AND/OR ITS LICENSORS.

You may not use or distribute this file without the express
written permission of Mentor Graphics or its authorized
distributor. This file is licensed only for use with
Sourcery CodeBench. No other use is permitted.
-->

<!ELEMENT board
(category?, properties?, feature?, initialize?, memory-map?, \
debuggerDefaults?)>

<!-- Board category to group boards list into the tree -->
```

¹ <https://sourcery.mentor.com/GNUToolchain/kbentry132>

```

<!ELEMENT category (#PCDATA)>

<!ELEMENT properties
  (description?, property*)>

<!ELEMENT initialize
  (write-register | write-memory | delay
   | wait-until-memory-equal | wait-until-memory-not-equal)* >
<!ELEMENT write-register EMPTY>
<!ATTLIST write-register
  address CDATA #REQUIRED
  value CDATA #REQUIRED
  bits CDATA #IMPLIED>
<!ELEMENT write-memory EMPTY>
<!ATTLIST write-memory
  address CDATA #REQUIRED
  value CDATA #REQUIRED
  bits CDATA #IMPLIED>
<!ELEMENT delay EMPTY>
<!ATTLIST delay
  time CDATA #REQUIRED>
<!ELEMENT wait-until-memory-equal EMPTY>
<!ATTLIST wait-until-memory-equal
  address CDATA #REQUIRED
  value CDATA #REQUIRED
  timeout CDATA #IMPLIED
  bits CDATA #IMPLIED>
<!ELEMENT wait-until-memory-not-equal EMPTY>
<!ATTLIST wait-until-memory-not-equal
  address CDATA #REQUIRED
  value CDATA #REQUIRED
  timeout CDATA #IMPLIED
  bits CDATA #IMPLIED>

<!ELEMENT memory-map (memory-device)*>
<!ELEMENT memory-device (property*, description?, sectors*)>
<!ATTLIST memory-device
  address CDATA #REQUIRED
  size CDATA #REQUIRED
  type CDATA #REQUIRED
  device CDATA #IMPLIED>

<!ELEMENT description (#PCDATA)>
<!ELEMENT property (#PCDATA)>
<!ATTLIST property name CDATA #REQUIRED>
<!ELEMENT sectors EMPTY>
<!ATTLIST sectors
  size CDATA #REQUIRED
  count CDATA #REQUIRED>

<!-- Definition of default option values for each debug interface -->
<!ELEMENT debuggerDefaults (debugInterface*)>
<!ELEMENT debugInterface (option*)>
<!ATTLIST debugInterface

```

```

name CDATA #REQUIRED
>
<!ELEMENT option EMPTY>
<!ATTLIST option
  name CDATA #REQUIRED
  defaultValue CDATA #REQUIRED
>

<!ENTITY % gdbtarget SYSTEM "gdb-target.dtd">
%gdbtarget;

```

All values can be provided in decimal, hex (with a 0x prefix) or octal (with a 0 prefix). Addresses and memory sizes can use a K, KB, M, MB, G or GB suffix to denote a unit of memory. Times must use a ms or us suffix.

The following elements are available:

- `<board>` This top-level element encapsulates the entire description of the board. It can contain `<category>`, `<properties>`, `<feature>`, `<initialize>` and `<memory-map>` elements.
- `<category>` The `<category>` element specifies a '.' separated categorization of this board (e.g., Vendor.Family) to allow grouping similar boards in a tree structure.
- `<properties>` The `<properties>` element specifies specific properties of the target system. This element can occur at most once. It can contain a `<description>` element.

It can also contain `<property>` elements with the following names:

- `banked-regs` The `banked-regs` property specifies that the CPU of the target board has banked registers for different processor modes (supervisor, IRQ, etc.).
- `has-vfp` The `has-vfp` property specifies that the CPU of the target board has VFP registers.
- `system-v6-m` The `system-v6-m` property specifies that the CPU of the target board has ARMv6-M architecture system registers.
- `system-v7-m` The `system-v7-m` property specifies that the CPU of the target board has ARMv7-M architecture system registers.
- `core-family` The `core-family` property specifies the ARM family of the target. The body of the `<property>` element may be one of `arm7`, `arm9`, `arm11`, and `cortex`.
- `system-clock` This property specifies the target clock frequency (in Hertz) after reset. It is used to configure flash programming algorithms.

<code><initialize></code>	The <code><initialize></code> element defines an initialization sequence for the board, which the Sprite performs before downloading a program. It can contain <code><write-register></code> , <code><write-memory></code> and <code><delay></code> elements.
<code><feature></code>	This element is used to inform GDB about additional registers and peripherals available on the board. It is passed directly to GDB; see the GDB manual for further details.
<code><memory-map></code>	This element describes the memory map of the target board. It is used by GDB to determine where software breakpoints may be used and when flash programming sequences must be used. This element can occur at most once. It can contain <code><memory-device></code> elements.
<code><memory-device></code>	This element specifies a region of memory. It has four attributes: <code>address</code> , <code>size</code> , <code>type</code> and <code>device</code> . The <code>address</code> and <code>size</code> attributes specify the location of the memory device. The <code>type</code> attribute specifies that device as <code>ram</code> , <code>rom</code> or <code>flash</code> . The <code>device</code> attribute is required for <code>flash</code> regions; it specifies the flash device type. The <code><memory-device></code> element can contain a <code><description></code> element.
<code><write-register></code>	This element writes a value to a control register. It has three attributes: <code>address</code> , <code>value</code> and <code>bits</code> . The <code>bits</code> attribute, specifying the bit width of the write operation, is optional; it defaults to 32.
<code><write-memory></code>	This element writes a value to a memory location. It has three attributes: <code>address</code> , <code>value</code> and <code>bits</code> . The <code>bits</code> attribute is optional and defaults to 32. Bit widths of 8, 16 and 32 bits are supported. The address written to must be naturally aligned for the size of the write being done.
<code><delay></code>	This element introduces a delay. It has one attribute, <code>time</code> , which specifies the number of milliseconds, or microseconds to delay by.
<code><description></code>	This element encapsulates a human-readable description of its enclosing element.
<code><property></code>	The <code><property></code> element allows additional name/value pairs to be specified. The property name is specified in a <code>name</code> attribute. The property value is the body of the <code><property></code> element.

Chapter 7

Next Steps with Sourcery CodeBench

This chapter describes where you can find additional documentation and information about using Sourcery CodeBench Lite and its components.

7.1. Sourcery CodeBench Knowledge Base

The Sourcery CodeBench Knowledge Base is available to registered users at the Sourcery CodeBench Portal¹. Here you can find solutions to common problems including installing Sourcery CodeBench, making it work with specific targets, and interoperability with third-party libraries. There are also additional example programs and tips for making the most effective use of the toolchain and for solving problems commonly encountered during debugging. The Knowledge Base is updated frequently with additional entries based on inquiries and feedback from customers.

7.2. Example Programs

Sourcery CodeBench Lite includes some bundled example programs. You can find the source code for these examples in the `share/sourceryg++-arm-none-eabi-examples` directory of your Sourcery CodeBench installation.

7.2.1. Other Examples

The subdirectories contain a number of small, target-independent test programs. You may find these programs useful as self-contained test cases when experimenting with configuring the correct compiler and debugger settings for your target, or when learning how to use the debugger or other features of the Sourcery CodeBench toolchain.

7.3. Manuals for GNU Toolchain Components

Sourcery CodeBench Lite includes the full user manuals for each of the GNU toolchain components, such as the compiler, linker, assembler, and debugger. Most of the manuals include tutorial material for new users as well as serving as a complete reference for command-line options, supported extensions, and the like.

When you install Sourcery CodeBench Lite, links to both the PDF and HTML versions of the manuals are created in the shortcuts folder you select. If you elected not to create shortcuts when installing Sourcery CodeBench Lite, the documentation can be found in the `share/doc/sourceryg++-arm-none-eabi/` subdirectory of your installation directory.

In addition to the detailed reference manuals, Sourcery CodeBench Lite includes a Unix-style manual page for each toolchain component. You can view these by invoking the `man` command with the pathname of the file you want to view. For example, you can first go to the directory containing the man pages:

```
> cd $INSTALL/share/doc/sourceryg++-arm-none-eabi/man/man1
```

Then you can invoke `man` as:

```
> man ./arm-none-eabi-gcc.1
```

Alternatively, if you use `man` regularly, you'll probably find it more convenient to add the directory containing the Sourcery CodeBench man pages to your `MANPATH` environment variable. This should go in your `.profile` or equivalent shell startup file; see Section 2.6, “Setting up the Environment” for instructions. Then you can invoke `man` with just the command name rather than a pathname.

¹ <https://sourcery.mentor.com/GNUToolchain/>

Finally, note that every command-line utility program included with Sourcery CodeBench Lite can be invoked with a `--help` option. This prints a brief description of the arguments and options to the program and exits without doing further processing.

Appendix A

Sourcery CodeBench Lite Release Notes

This appendix contains information about changes in this release of Sourcery CodeBench Lite for ARM EABI. You should read through these notes to learn about new features and bug fixes.

A.1. Changes in Sourcery CodeBench Lite for ARM EABI

This section documents Sourcery CodeBench Lite changes for each released revision.

A.1.1. Changes in Sourcery CodeBench Lite 2012.03-56

New Sourcery CodeBench Lite branding. Sourcery G++ has been renamed to Sourcery CodeBench. This change affects the names of the default installation directory and installer-created shortcuts, but no internal pathnames or tool names within the installation directory have been changed.

Fix for internal compiler error. A bug that caused GCC to report an internal compiler error in `push_minipool_fix` has been fixed.

Internal compiler error with NEON intrinsics. A compiler bug has been fixed that caused internal compiler errors when using certain NEON intrinsics.

Nondeterministic code generation bug fix. A GCC bug has been fixed that caused nondeterministic code generation for some input files when optimizing.

Fix for compiler hang. A bug that caused GCC to become stuck in an infinite loop in the optimizer has been fixed.

Internal compiler error. A GCC bug has been fixed that caused an internal compiler error when sign extending the result of an array subscript expression with an index greater than 255.

GCC version 4.6. Sourcery CodeBench Lite for ARM EABI is now based on GCC version 4.6. For more information about changes from GCC version 4.5 that was included in previous releases, see <http://gcc.gnu.org/gcc-4.6/changes.html>.

Fix for internal compiler error. A GCC bug has been fixed that caused an internal compiler error when using pointer casts in `C++0x constexpr` initialization expressions.

ARM VFP9-S errata workaround. A compiler workaround for ARM Errata Notice GENC-010704 (760019: Canceled FDIV or FSQRT can be executed twice) has been implemented.

Fix for bit-field optimization bug. A compiler bug that caused incorrect code to be generated for programs using bit-fields has been fixed.

GCC version 4.6.3. Sourcery CodeBench Lite for ARM EABI is now based on GCC version 4.6.3. For more information about issues that have been fixed since version 4.6.1, see <http://gcc.gnu.org/gcc-4.6/changes.html>.

Compiler crash fixed. A GCC bug that occasionally caused an internal compiler error during register allocation has been fixed.

Map file name demangling bug fix. GCC now properly passes the `--demangle` and `--no-demangle` options to the linker to control map file output. The default behavior on all hosts is now to demangle C++ names.

GCC stack usage improvement. GCC now generates better code for stack allocation in some cases when compiling with `-fno-strict-aliasing`.

ARM miscompilation fix. A bug has been fixed that caused miscompilation of some expressions involving the minimum or maximum idiom, such as `(a > 0) ? a : 0`.

Register allocation bug fix. A bug in the register allocator that caused incorrect code generation has been fixed.

Linker `--gc-sections` option bug fix. A bug has been fixed that caused the linker to incorrectly remove the `.debug_types` section when using the `--gc-sections` option.

Linker `--gc-sections` bug fix. A linker bug that incorrectly caused undefined references to be diagnosed when the `--gc-sections` option is used has been fixed.

Binutils version 2.21. Sourcery CodeBench Lite for ARM EABI is now based on binutils version 2.21.

Assembler crash. The assembler now warns when there is line information for the `*ABS*` section, rather than crash. This can occur when the `.offset` directive is used incorrectly.

Installer failure during upgrade. Some recent releases were affected by an installer bug on Windows hosts that caused installing a newer version of Sourcery CodeBench Lite into the same directory to fail with the error `Sourcery CodeBench Lite for ARM EABI upgrade failed`. This bug has now been fixed, but the affected releases cannot be upgraded. As a workaround, uninstall the older release before installing the new version.

CS3 bug fix for Xilinx Zynq-7000. A bug that caused undefined symbol errors in the CS3 library when linking programs for the Xilinx Zynq-7000 has been fixed.

Freescale i.MX53 QSB support. Sourcery CodeBench Lite now supports the Freescale i.MX53 QSB board.

Fix for crash in GDB `maint print arch`. A bug in the GDB command `maint print arch` that sometimes caused GDB to crash has been fixed.

C++ debugging bug fix. A GDB bug has been fixed that caused GDB to fail to find enum constants in base classes when debugging C++ code.

Fix for crash in GDB. A memory corruption bug in GDB has been fixed that under very rare circumstances made it crash or exhibit other unpredictable behavior. On GNU/Linux hosts, this bug caused crashes with an error message similar to: `*** glibc detected *** arm-none-eabi-gdb: free(): invalid next size (normal): 0x09466198 ***` followed by a backtrace.

GDB interrupt handling bug fix. A bug in GDB has been fixed that caused it to sometimes fail to interrupt lengthy single-step operations (as by a `Ctrl+C` when using GDB from the command line).

Fix debugger remote target interruption. A bug in GDB's handling of requests to interrupt execution on a remote target has been fixed that caused it to stop the target but not emit a stopped MI record.

Fix GDB crash during connection to debug agent. A bug has been fixed that caused GDB to crash while connecting to any debug agent through standard IO where the debug agent had detected an early error and terminated the communication.

GDB internal error fix. A bug has been fixed that caused GDB to produce messages of the form: `warning: (Internal error: pc 0x1000a0 in read in psyntab, but not in syntab.)` when taking the addresses of symbols from objects added with the `add-symbol-file` command.

Improved disassembler performance in the debugger. GDB's disassembler has been improved to use more efficient memory access on remote targets.

Fix GDB crash in debugging Thumb assembly routines. A bug in GDB has been fixed that caused a crash when debugging Thumb assembly routines that switch stacks by writing the stack pointer in the function prologue.

Debug Sprite option defaults. The Sourcery CodeBench Debug Sprite now uses default option values specified in board configuration files. Options included in the device URL override the default values.

Changes to host operating system requirements. The minimum required Microsoft Windows OS needed to run Sourcery CodeBench Lite is now Windows XP (SP1).

A.1.2. Changes in Sourcery G++ Lite 2011.03-42

Variable Length Array (VLA) alignment bug. A compiler bug that resulted in incorrectly aligned variable length arrays (VLA) in leaf functions has been fixed.

Cortex-R5 support. Sourcery G++ now includes support for ARM Cortex-R5 processors. To compile for these processors, use `-mcpu=cortex-r5`.

Inline assembly and volatile fields. A bug has been fixed that caused the compiler to incorrectly reject inline asm statements referring to volatile class/struct fields with errors such as `error: output number 1 not directly addressable`.

Fixed-point arithmetic support. Experimental compiler support has been added for fixed-point arithmetic on ARM, as described in the draft ISO/IEC technical report TR 18037. Specialized instructions defined in recent architecture versions for performing saturating arithmetic, etc. are used when available, but are not a prerequisite for using the new language features. See Section 3.5, "Fixed-Point Arithmetic" for further details.

C++ constructor bug fix. A compiler bug has been fixed that caused incorrect code for C++ constructors for some class hierarchies that use virtual inheritance and include empty classes. At runtime, the incorrect constructors resulted in memory corruption or other errors.

Thumb debug information fix. A compiler bug that resulted in incorrect debug information for Thumb code has been fixed. The incorrect information prevented single stepping through some code.

Internal compiler error with pointer casting. A compiler bug has been fixed that caused internal compiler errors when accessing double-word memory locations with casted pointers under ARM mode.

Unaligned access support. The compiler now generates more efficient code for accessing packed data structures and for copying small blocks of unaligned data when targeting architectures that permit unaligned word/halfword accesses. This feature can be controlled by the `-munaligned-access` and `-mno-unaligned-access` options, and is enabled by default for ARMv6 processors and above, except for ARMv6-M.

Internal compiler error under Thumb mode. A compiler bug has been fixed that caused internal compiler errors when generating Thumb code.

Xilinx Zynq-7000 board support. Sourcery G++ Lite now includes CS3 board support for the Xilinx Zynq-7000.

Debugging M-profile targets with third-party GDB stubs. A bug in GDB has been fixed that caused the error `Remote 'g' packet reply is too long` with ARMv6-M and ARMv7-M targets. The error was reported when connecting to some third-party GDB stubs, including SEGGER GDB Server and OpenOCD, but did not affect the Sourcery G++ Debug Sprite.

A.1.3. Changes in Sourcery G++ Lite 2011.03-13

GCC fixes for `-fstrict-volatile-bitfields`. GCC now honors `-fstrict-volatile-bitfields` when a bitfield is not declared volatile initially, but an object including bit fields is cast to volatile. Also, a bug was fixed that caused incorrect code to be generated for some stores to volatile bit fields when `-fstrict-volatile-bitfields` is enabled.

Compiler optimization improvements. The compiler has been enhanced with a number of optimization improvements, including:

- Smaller and faster code for compound conditionals.
- Removal of superfluous sign and zero extensions.
- Improved code for multiply-and-accumulate operations on ARM.
- Faster code when tuning for Cortex-M series processors.

Internal compiler error with NEON intrinsics. A compiler bug has been fixed that caused internal compiler errors when using certain NEON intrinsics.

GCC version 4.5.2. Sourcery G++ Lite for ARM EABI is now based on GCC version 4.5.2.

GCC code generation bug for casts to `volatile` types. A compiler bug has been fixed that sometimes caused incorrect code for references to pointers to types with `volatile` casts.

Incorrect optimization fix. An optimizer bug that in rare cases caused incorrect code to be generated for complex AND and OR expressions containing redundant subexpressions has been fixed.

Incorrect C++ warning fixed. A bug in GCC has been fixed that caused spurious warnings about lambda expressions in C++ code that does not use them.

GCC fixes for NEON in big-endian mode. Several compiler bugs have been fixed that could lead to incorrect code when using NEON in big-endian mode. The problems only manifested when using the auto-vectorizer (enabled by default at the `-O3` optimization level) with the `-mvectorize-with-neon-quad` option.

Incorrect code for built-in comparison functions. A bug has been fixed that sometimes caused GCC's built-in comparison functions, such as `__builtin_isgreaterequal`, to incorrectly raise exceptions when invoked on unordered floating-point arguments.

C++ exception handling. A defect in the implementation of the EH-ABI specification has been fixed. The defect affected the catching of pointer types in code generated by the ARM RealView® compiler but using the Sourcery G++ runtime libraries. The fix also retains backward compatibility with existing GCC-compiled code.

GCC bug where accesses to volatile structure fields are optimized away. A bug has been fixed where accesses to volatile fields of a structure were sometimes incorrectly optimized away if the structure instance was defined as non-volatile.

Internal compiler error fixes. Two bugs have been fixed that caused compiler crashes in rare cases. The first bug involved code with multiple comparison operations, and the second one involved `char` to `int` conversion.

Thumb-2 assembler validation fix. The assembler now correctly rejects Thumb-2 `ADD`, `ADDS`, `SUB`, and `SUBS` instructions that have an invalid shift operand. Previously, invalid shift values were accepted and generated unpredictable instructions.

Objdump fix for multiple input files. The `Objdump` utility did not produce correct disassembly when processing multiple input files. This has been fixed.

CS3 interrupt handlers. CS3 now provides separate ISR functions for each core processor exception, rather than aliasing them all to a single interrupt handler. This provides more useful backtrace information in the debugger.

A.1.4. Changes in Sourcery G++ Lite 2010.09-51

GCC fix for duplicated symbols. A GCC optimizer bug that caused multiple definitions of local symbols has been fixed. Code affected by the bug was rejected by the assembler.

NEON code generation fix. A GCC bug has been fixed that resulted in an assembler error `VFP/Neon double precision register expected`.

Static data size improvement at -Os. When optimizing for size, the compiler no longer implicitly adds padding bytes to align static and local arrays on word boundaries. This fixes static data size regressions introduced since GCC 4.4. The additional alignment is still used when optimizing for speed.

New -fstrict-volatile-bitfields option. The compiler has a new option, `-fstrict-volatile-bitfields`, which forces access to a volatile structure member using the width that conforms to its type. This option is enabled by default to conform to the ARM EABI. Refer to the GCC manual for details.

Internal compiler error fixes. A bug has been fixed that caused the compiler to crash on code containing a `typedef` alias for `__builtin_va_list` with option `-femit-struct-debug-baseonly`. A second bug has been fixed that caused a crash when compiling code using C99 variable-length arrays. Additionally, a compiler crash on code using 64-bit integer multiplications with NEON vectorization enabled has also been fixed.

NEON narrowing-move instructions. The compiler now supports narrowing-move instructions when auto-vectorizing for NEON. Loops accessing arrays of `char` or `short` values are now more likely to be vectorized.

Improved support for atomic memory builtins. The compiler support for built-in atomic memory access operations on ARMv7 targets has been improved. These builtins are documented in the GCC manual.

Linker debug information fix. A bug in linker processing of debug information has been fixed. The bug sometimes prevented the Sourcery G++ debugger from displaying source code if the executable was linked with the `--gc-sections` option.

Absolute branch bug fixes. A bug that caused the assembler to crash on a branch to an absolute address has been fixed. Linker handling of the resulting relocations has also been improved. Previously this caused an invalid switch to ARM mode on ARMv7-M devices.

VMOV instruction bug fix. A bug that caused the assembler to incorrectly reject certain valid immediate operands for the VMOV instruction has been fixed.

Debugger warnings quieted. GDB no longer prints RMT ERROR diagnostics on connection to the Sourcery G++ Debug Sprite. In spite of the alarming appearance of the messages, they were not actually indicative of a serious problem.

A.1.5. Changes in Sourcery G++ Lite 2010.09-22

Changes to Sourcery G++ version numbering. Sourcery G++ product and Lite toolchains now uniformly use a version numbering scheme of the form 2012.03-56. The major and minor parts of the version number, in this case 2012.03, identify the release branch, while the final component is a build number within the branch. There are also new preprocessor macros defined by the compiler for the version number components so that you may conditionalize code for Sourcery G++ or particular Sourcery G++ versions. Details are available in the [Sourcery G++ Knowledge Base](#)¹.

GCC fix for reference to undefined label. A bug in the optimizer that caused GCC to emit references to undefined labels has been fixed.

Precision improvement with vectorization enabled. The GCC auto-vectorizer no longer uses NEON floating-point instructions unless the `-funsafe-math-optimizations` option (implied by `-ffast-math`) is specified. This is because NEON hardware does not fully support the IEEE 754 standard for floating-point arithmetic. In particular, very small quantities may be flushed to zero.

Alignment attributes. A bug has been fixed that caused the compiler to ignore alignment attributes of C++ static member variables where the attribute was present on the definition, but not the declaration.

naked attribute semantics. The `naked` function attribute now also implies the `noinline` and `noclone` attributes. This fixes bugs resulting from invalid optimizations of functions with this attribute.

Stack corruption bug fix. A bug in GCC has been fixed that caused stack corruption in functions with the `interrupt` attribute.

GCC bug fix for push multiple instruction generation. A bug has been fixed that caused GCC to generate incorrect push multiple instructions, causing an assembler warning `register range not in ascending order`.

Thumb-2 internal compiler error fix. A bug has been fixed that caused the compiler to crash when compiling Thumb-2 code using 64-bit integer arithmetic.

Compiler optimization improvements. The compiler has been enhanced with a number of optimization improvements, including:

- More efficient assignment for structures containing bitfields.
- Better code for initializing C++ arrays with explicit element initializers.
- Improved logic for eliminating/combining redundant comparisons in code with nested conditionals.
- Better selection of loop variables, resulting in fewer temporaries and more efficient register usage.
- More optimization of references to globals in position-independent code.

¹ <https://support.codesourcery.com/GNUToolchain/kbentry1>

- Various Thumb code generation improvements.
- Better code when constant addresses are used as arguments to inline assembly statements.
- Better code for copying small constant strings.
- Improved tuning for Cortex-M4 processors.
- Cortex-A9 specific tuning for VFP and NEON instructions.
- Use of more NEON features.

Preprocessor symbols for floating-point calling convention. Built-in preprocessor symbols `__ARM_PCS` and `__ARM_PCS_VFP` are now defined to indicate the current floating-point calling convention.

GCC version 4.5.1. Sourcery G++ Lite for ARM EABI is now based on GCC version 4.5.1. For more information about changes from GCC version 4.4 that was included in previous releases, see <http://gcc.gnu.org/gcc-4.5/changes.html>.

New `-Wdouble-promotion` warning option. The compiler has a new option, `-Wdouble-promotion`, which enables warnings about implicit promotions of `float` values to `double`. This option is useful when compiling code for processors (such as ARM Cortex-M4) that have hardware support for single-precision floating-point arithmetic only, where unintentional use of double precision results in dramatically slower code.

Linker bug fix. A bug that caused the linker error `relocation truncated to fit: R_ARM_THM_JUMP24` when linking some Thumb-2 applications has been fixed.

Assembler PC-relative store fix. A bug that caused the assembler to reject some valid PC-relative store instructions has been fixed. It now issues a warning instead for architectures where these instructions are deprecated.

ARMv7-A linker bug fix. A bug in the linker support for `--fix-cortex-a8`, which is enabled by default when linking ARMv7-A objects, has been fixed. Programs affected by the bug sometimes crashed with segmentation fault or illegal instruction errors.

Smaller C++ programs with `-g`. An assembler bug has been fixed that caused unnecessary references to exception-handling routines from C++ programs when debug information is enabled. For programs that do not otherwise use exceptions, this change results in smaller code size.

Additional validation in the assembler. The assembler now diagnoses an error, instead of producing an invalid object file, when directives such as `.hidden` are missing operands.

Assembler PC-relative load fix. An assembler bug that caused the assembler to reject some references to global symbols has been fixed. This bug affected Thumb instructions of the form `ldr r0, symbol`.

Strip bug fix. A bug in the `strip` and `objcopy` utilities, which resulted in stripped object files that the linker could not recognize, has been fixed.

Binutils update. The binutils package has been updated to version 2.20.51.20100809 from the FSF trunk. This update includes numerous bug fixes.

Additional alignment in CS3-defined linker scripts. Sourcery G++ now ensures 8-byte alignment at additional points in CS3-defined linker scripts. Previously, placing a symbol in certain sections broke the initialization of the `.data` and/or `.bss` sections.

Newlib update. The Newlib package has been updated to version 1.18.0, with additions from the community CVS trunk as of 2010-08-12. This update provides additional wide-character functions, along with other bug fixes and enhancements.

malloc fix. A bug that sometimes caused `free` to dereference an invalid address has been fixed. The bug was caused by incorrect handling within `malloc` of calls to `sbrk` from outside of `malloc`.

Improved support for debugging RealView® C++ programs . GDB has been enhanced to handle some debug information contained in binaries produced by the ARM RealView® compiler. Formerly, GDB sometimes crashed on programs which use C++ templates. Another bug has been fixed that caused GDB to fail to place breakpoints in binaries produced by the ARM RealView® compiler when the source file location for the breakpoint was specified as an absolute pathname.

GDB update. The included version of GDB has been updated to 7.2.50.20100908. This update adds numerous bug fixes and new features, including improved C++ language support, a new command to save breakpoints to a file, a new convenience variable `$_thread` that holds the number of the current thread, among many other improvements.

GDB crash fix. A bug has been fixed that caused GDB to crash on launch if the environment variable `CYGPATH` is set to a program that does not exist or cannot be executed.

Debug Sprite abnormal termination bug fix. The Sourcery G++ Debug Sprite no longer terminates abnormally if GDB is killed while the target is waiting for semihosted I/O to complete. The bug was only triggered when running GDB on a Windows host.

Semihosting support for `gettimeofday`. The Sourcery G++ Debug Sprite now provides a semihosted implementation of the `gettimeofday` C library function.

A.1.6. Changes in Older Releases

For information about changes in older releases of Sourcery G++ Lite for ARM EABI, please refer to the Getting Started guide packaged with those releases.

Appendix B

Sourcery CodeBench Lite

Licenses

Sourcery CodeBench Lite contains software provided under a variety of licenses. Some components are “free” or “open source” software, while other components are proprietary. This appendix explains what licenses apply to your use of Sourcery CodeBench Lite. You should read this appendix to understand your legal rights and obligations as a user of Sourcery CodeBench Lite.

B.1. Licenses for Sourcery CodeBench Lite Components

The table below lists the major components of Sourcery CodeBench Lite for ARM EABI and the license terms which apply to each of these components.

Some free or open-source components provide documentation or other files under terms different from those shown below. For definitive information about the license that applies to each component, consult the source package corresponding to this release of Sourcery CodeBench Lite. Sourcery CodeBench Lite may contain free or open-source components not included in the list below; for a definitive list, consult the source package corresponding to this release of Sourcery CodeBench Lite.

Component	License
GNU Compiler Collection	GNU General Public License 3.0 http://www.gnu.org/licenses/gpl.html
GNU Binary Utilities	GNU General Public License 3.0 http://www.gnu.org/licenses/gpl.html
GNU Debugger	GNU General Public License 3.0 http://www.gnu.org/licenses/gpl.html
Sourcery CodeBench Debug Sprite for ARM	CodeSourcery License
CodeSourcery Common Startup Code Sequence	CodeSourcery License
Newlib C Library	BSD License. For the text of the license and a complete list of copyright holders, see Section B.3.2, “Newlib”.
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